reservoirs and conveyed to the farm by gravitation. Thus, pumping would be rendered unnecessary, and an abundant supply may be had at small cost.

The distribution will be most conveniently made upon each field by using hose or other surface pipes, jetting the water upon the land from convenient points, and it may be thrown in the shape of rain by any common labourer (with a little instruction.) In this way, a labourer with a boy as his assistant may effectually water ten acres in a day, at a cost of about 3s. for wages: and, adding 2s. for the cost of the fetching and removal of the surface pipes by a horse and cart, with a sum to cover the interest of the outlayed money, chargeable to each application, the whole will amount to 5s., being at the rate of 6d. per acre; and, adding 6d. per acre for pumping, the full cost will be 1s. per acre.

This to a practical farmer will at once appear an insignificant charge for a soaking shower of rain in a dry period; and, if it is in summer weather, when there is heat, the growth of whatever plants are in the ground will be greatly promoted; and, what is very important, the permanent injury, by stoppage of growth for a period, which takes place by excessive and continued drought, will be avoided; so that, when the natural moisture returns, the plants will proceed in their growth in a healthy condition, and the certainty of an early and abundant crop will be the result. In the flat countries, where water cannot be made available from reservoirs in the upper country, the whole water required may be pumped by the steam-engine usually employed for thrashing the grain, and at an extremely small cost; and since it has been elsewhere demonstrated that manure may be most efficiently applied in the liquid form, the watering pipes and apparatus can be used with great advantage in distributing the manure, by which they would perform the double office of supplying abundance of water in dry seasons, and of distributing the manure at all seasons, when proper to apply it.

In the application of liquid manure, much dilution is found to be absolutely necessary: and the farmer should always be provided with an abundant supply of water, wherewith to mix his liquid manure from the farm, or to dissolve and mix with such artificial manures as he may find it profitable to employ; in this way, the most minute shade of nourishing matter may be given at such times as the plants may require. It has been ascertained by the analysis of drainage water, that a considerable portion of the dung put upon land passes off with the superabundant rain water. I, therefore, propose that, upon every farm, there should be a pond or reservoir to catch and store up the drainage water of the wet season, that it may be thrown upon the land in dry periods—thus saving, as far as it is possible, the enriching matter, which would otherwise be lost. This points to the lowest part of the farm as the most proper site for the homestead or farm-buildings, that the steam-engine may be contiguous, at the same time, to the farmstead and to the reservoir. Such position for the farmstead would be most suitable in another important point of view. The system recently called high farming would seem to be imperatively called for in the present condition of the agriculturists of this country, when a greater proportion of rearing and feeding of cattle must be carried out on every farm, so that a larger amount of manure may be produced, with a more profitable application of the food raised. To this end the liquid manure and distribution by pipes will greatly contribute; whilst having the farmstead in a low position will assist in the carting home of the increased green crops for house-feeding, being chiefly down hill, and will be, to a certain extent, advantageous for the carrying home of grain crops as well. The farmstead will generally thus be in a more sheltered position, which in all respects will be advantageous, except with the single exception of drying of grain in the stack, which process can be placed under the more immediate control of the farmer by cheap and efficient artificial means.

All over the Lothians, and the other more advanced districts in Scotland, the steam-engine is a common appendage to every farmstead of any extent, for the purpose of thrashing the grain, cutting the straw and roots, and bruising grain, &c.; and as such engines are employed but a very small portion of time, a forcing pump may be attached for the purpose of pumping water and liquid manure. The application of the common liquid manure of a farm has hitherto been an uphill work, and must always be so when a manure cart is employed as the means of conveyance and distribution; and the farmers who have taken the trouble to ascertain the cost of carrying out their liquid manure by cart must have long ago found that it is very great, and that in most instances (to use a Scotch phrase), "The cost will o'ergang the profit." The application is generally limited to grass lands, where much injury is frequently done, by so much carting as is necessary. When the liquid is applied in dry periods the grass is frequently injured by the strength and acrimony of the fluid: to dilute it with water sufficiently would add very much to the expense of the conveyance and distribution by cart; but when pipes and a steam-engine are employed, a large amount of dilution adds very little to the necessary expense.

The permanent pipes should be placed two, or two and a half feet under the surface, so as to remove them from the influence of severe frost, and from any interference with the deepest working of the land, and it will be sufficient that there be only one or two points of communication with these pipes in each field, as removable pipes, laid upon the surface, are found sufficient to convey the liquid to the points from which the water or liquid manure has to be jetted. These pipes, which are made with slip-joints, can be removed from field to field, so that one, or at most two sets of removable pipes will suffice for a moderate-sized farm. I have thus endeavoured to lay before my readers an outline of my plan for an artificial supply of moisture to the soil.

PARKER'S WATER WHEEL.

This important improvement is now extensively in use in nearly every State in the Union. By the most careful scientific tests, and by observations in many instances in which it has been substituted for overshot and high-breast or pitch-back wheels, it has been fully proved to be more effective in point of economy of water than gravity wheels; while its simplicity, its not being impeded by backwater, or obstructed by ice, its convenience of arrangement for inspection and management, the smallness of the space it occupies, its great durability, its not being liable to get out of order, and its cheapness, especially for great powers, are important advantages not possessed in an equal degree by any other motor.

Fig. 1.

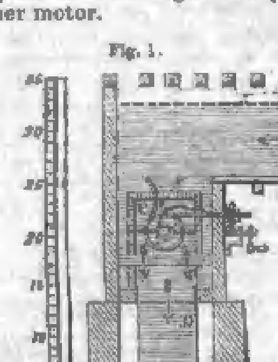
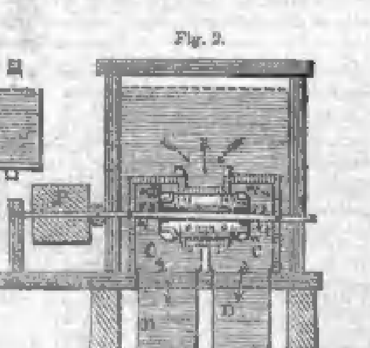


Fig. 2.



The above figures represent one of these wheels recently established in the Agawam Canal Company's Cotton Mill, at West Springfield, Mass.; fig. 1, being an elevation or vertical section through the axis of the wheel; fig. 2, an elevation across the shaft, representing a section of the penstock and draft tubes, and a profile of the helical inlet The parts of the drawing have their true proportions according to the scale.

The fall of water operating the wheel is 31 feet; its full power is estimated at 250-horse power, with an expenditure of 6396 cubic feet of water per minute. The wheel consists of a pair of reaction wheels or rims *w*, of a modified and improved form, arranged on a horizontal shaft, and a double helical sluice *o*, which conducts the water into the wheels with a lively annular motion in the direction in which the wheel moves. The wheel, with its helical sluice, is placed within the penstock, or reservoir supplying it, and is entirely surrounded with water, the extremities of the shaft only protruding from the sides; its axis is 20 feet high from the surface of the tail water. The water passes from the wheels or rims into two air-tight chambers or cases *c*, called "draft boxes," from which it passes into two air-tight iron tubes *d*, called "draft tubes," which terminate and discharge the water beneath the surface of the lower level. The air being entirely excluded from

these draft boxes and tubes, and their sections being many times greater than the aggregate openings of the wheel, the water within them descends slowly, being held up by the pressure of the atmosphere on the lower level. It consequently acts by its gravity in giving the water force and velocity, in its passage through the helical inlets and wheel, as effectually as it would if it were over the wheel and acted by its pressure as head water. The wheel is 40 inches in diameter, and, at its proper working speed, makes 220 revolutions per minute. The power is transmitted directly to the line shafts of the mill by belts, from drums or pulleys *p*, on the extremities of the shaft of the wheel. The drums are 6 feet in diameter, and the pulleys on the line shafts 10 feet; the belts consequently travel at the rate of 4148 feet per minute, or a little more than 47 miles per hour, giving the line shafts 132 revolutions per minute. With the gate *t*, (which admits the water to the wheel,) a little more than half drawn, the wheel drives with full speed 7000 throstle spindles, and about half of the additional line shafting necessary for the balance of 16,000 spindles, (the number the mill is to contain when filled), a number of iron and wood lathes, circular saw, &c.

The water required to effect this is about 4500 cubit feet per minute. From a comparison of this result with that of wheels previously erected for propelling cotton mills, working with the gate partly drawn, it is confidently anticipated that the full power of the wheel will drive 13,000 spindles. The company expect to attach machinery sufficient to require the whole power in the course of a few months. The whole cost of the wheel, with all the parts pertaining to it, was about 5000 dollars.

This wheel was substituted for a pitch-back or high-breast wheel, 32 feet in diameter and 17 feet wide, which was operated by the same fall of water. It was made almost entirely of iron, the buckets and soling only being of wood. The quantity of water required to propel it was estimated at 4800 cubic feet per minute. The greatest power that could be got from it was only sufficient for 5000 spindles; another thousand was attached, but it could not be made to drive them with sufficient speed. It was erected early in the present year, and, after running about three months, constantly requiring expensive repairs, it was deemed expedient by the company to remove it, and substitute one of Parker's, which, as yet, appears to the directors and managers of said company to possess many very superior advantages, as compared with the old wheel, there being much less liability to failure. Another important advantage is in getting up the required speed for the machinery without the use of intervening gearing; thus saving a heavy expense in repairs, and a large amount of oil.

Parker's wheels, in the form here represented, are now in operation in the mills of the following proprietors, to whom those interested are referred for a confirmation of that which is here stated.

	Horse power.	Feet fall.
T. F. Plunkitt, Pittsfield, Mas., Cotton Mill	65	14
J. Barker & Brother, Pittsfield, Mass., Casinet Mill	15	11
Plattner & Smith, Lee, Mass., Woollen Mill	45	9
Glendale Woollen Company, Stockbridge, Mass., Woollen Mill	65	14
Berkshire Woollen Company, Great Barrington, Mass.	45	9
White & Sheffield, N. Y. City or Jos. Kingsland, Saugerties, N. Y. } Saugerties Paper Mill.	140	26
Jos. Bailey, Douglasville, Berks Company, Pa., Rolling Mill	65	14
New Brunswick Manufacturing Company, J. Stark, Agent, New Brunswick, N. J., Cotton Mill	38	12
Agawam Canal Company, D. Jakeworth, Agent, West Springfield, Mass., Cotton Mill	250	31

With the exception of the last-mentioned, these wheels have been in operation from one to five years, and so far as has come to the knowledge of the writer, neither of them has required repairing to the amount of a single dollar, nor been out of working order for an hour, since they were first put in operation.—*American Franklin Journal.*

PROCEEDINGS OF SCIENTIFIC SOCIETIES.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Jan. 7.—T. Bellamy, Esq., V.P., in the Chair.

Mr. Fergusson read a paper 'On the Architecture of Southern India,' which we give, in full, in another portion of the *Journal*, p. 37.

The following letter, from Mr. Edward Falkener, was then read:—

Dear Sir,—I just have time to write this hasty memorandum of the recent excavations at Rome. On the declaration of the Republic at Rome, the government, actuated by the triple motive of pride in the ancient glory of their ancestors, love of the fine arts, and a desire to provide for the temporary necessities of the indigent part of the population, ordered excavations to be commenced in the Roman Forum. The work was carried on with great energy, notwithstanding the declamations of the anti-Republicans, who inveighed against the barbarism of cutting down the old trees in the Campo Vaccino; but who now with equal ardour praise up the French government for continuing the excavation. Little, however, has at present been discovered, although a large quantity of earth has been turned up. The part excavated has been that adjoining the south-eastern side of the Column of Phocas. The only remains brought to light are some unimportant brick walls of the late Empire, and a stone pavement apparently of the Forum, with one continued step at the side, which probably marks the line of portico, although no columns were found to justify this supposition. The works, however, still continue, and very sanguine expectations are held by the *archæologues* of Rome relative to the result. Other excavations have been conducted in the Forum of Trajan, but with no better success, for with the exception of some fragments of sculpture, no remains of interest have been discovered.

More important fruits have been obtained in the Trastevere. In pulling down and rebuilding an old house, a very fine statue of Greek art was found, representing an athlete, who, after issuing from the thermæ, is represented cleaning his left arm from the perspiration of the bath with a strigil. It is of white marble, and rather more than the size of life. Again, in another part of the Trastevere, while removing the paving stones and earth from the carriage-way, I believe for one of the barricades, a large bronze horse was discovered, which is esteemed of early art from the short neck and other peculiarities displayed in it. The near fore leg has unfortunately been crushed and shattered, but no part of it is wanting, and it is considered that it can easily be restored. The seat is wanting, and from that circumstance it is difficult to say whether an equestrian figure was attached to it. This work of art has been placed in the Capitoline Museum, and the athlete in the Vatican. Lastly, in pulling down an old house in the Via Graziosa, near Sa. Maria Maggiore, some highly interesting remains were discovered of an ancient Roman house, consisting of several fresco paintings on a brick wall. From the circumscribed nature of the ground, there being other houses on each side, further excavation was impossible; but every precaution has been taken for the preservation of what has yet been discovered. The paintings represent the adventures of Ulysses, a circumstance which is highly interesting, from the fact that this is one of the subjects recommended to us by Vitruvius, for the decoration of private edifices. The paintings are moreover remarkable from having the name of the figures scratched with a point over the head of each figure. At the present moment eight of these paintings have been exposed. Immediately above these frescoes, on the *first floor*, are three semicircular-headed windows, the lower *voussoirs* on each side were found in their place, though the crown of the arches had fallen in or been removed. They have since been restored. Again, on the *second floor*, on a cross wall lying at right angles with the other wall, and forming the party wall of the adjoining house, the base of a marble column of the Corinthian or Composite order, and of good style, was found *in situ*, which, whether we regard the dimensions, about 20 inches diameter, or the height at which it was found, renders it of the highest interest as connected with the study of the domestic architecture of the ancients. It is extraordinary that these remains should have existed above ground for so many ages. Apologising for this hurried description,

I am, &c.,

Thos. L. Donaldson, Esq., Prof., &c. — Edward Falkener.

INSTITUTION OF CIVIL ENGINEERS.

Jan. 8.—William Cubitt, Esq., President, in the Chair.

This evening was devoted to the reading of the address from the President, on taking the Chair for the first time after his election, and which is given at length in another portion of the *Journal*, p. 41.

Jan. 15.—The paper read, was "*An Account of the Blackfriars Landing Pier.*" By Mr. F. Lawrence.

This pier commences on the Middlesex side of the river, to the east of Blackfriars Bridge, at Chatham-place, and continues parallel to the bridge, and at a distance of forty feet from it, for a length of one hundred and eighty-five feet. The body of the pier (exclusive of the head) is supported on four

piers, two of which consist of a single row, and two of a double row of piling, forming three spans of fifty feet each, and having about eight feet headway under them at high water. The floating barge, or dumby, on which the passengers land, is one hundred feet long and twenty-five feet wide, rising and falling with the tide, in grooves at each end, formed by piles and protected by dolphins. The connection between the dumby and the pier is by a moveable stage eight feet wide and fifty feet long, secured to the pier head, at one end by a hinge joint, and the other end similarly connected to a flight of steps on wheels, which moves on a tramway fixed to the deck of the barge. The principal portion of the timber used in its construction was fir; but the whole, whether of fir or oak, was impregnated by Payne's process—those portions below high-water mark being further protected by a coating of Stockholm tar. The whole of the cast and wrought iron work was galvanised.

The Corporation of London had observed the necessity for an improved landing place, so early as 1841, but it was not until a fatal accident occurred in 1844, that any decided steps were taken in the matter: then Messrs. Walker and Burges received instructions to prepare a design, which was approved, and the pier was commenced in March 1845, and completed in October of the same year, under the superintendence of Mr. Hewett, M. Inst. C.E. The total cost was about 4,000*l.*

The next paper read was a "*Description of a Timber Bridge, erected over the River Ouse, on the line of the Lynn and Ely Railway.*" By Mr. J. S. Valentine, M. Inst. C.E.

The total length of this bridge was four hundred and fifty feet, divided into eleven bays, ten of thirty feet span each, and one over the river of one hundred and twenty feet span on the square, and one hundred and twenty-one feet six inches on the skew. This river-opening consisted of three laminated timber bows, resting upon stone piers, the material for which was procured from the New Leeds Quarries. The dimensions of the bows were, length of chord, one hundred and twenty-one feet six inches; versed vine, fourteen feet two inches; and their depth, three feet eight inches; the width of the outer bows was two feet two inches, that of the centre bow two feet nine inches. They were formed of fifteen layers of three inch deals, abutting upon a cast-iron plate, bolted to the tie-beams, which consisted of two whole timbers scarfed and bolted together. Each tie-beam was suspended from the bows by thirteen wrought-iron rods, two inches in diameter, and between these diagonal struts were fitted. Transverse joists, notched on to the tie-beams, extended across the whole width of the bridge, and on these the rail bearers were laid, the intervening spaces being filled with three inch deals, laid longitudinally.

The works were commenced in the autumn of 1846, and completed in October 1847; the total cost of the superstructure being about 3,744*l.* When tested, by placing three locomotive engines on each line of rails, the total deflection was only three-eighths of an inch.

Jan. 22.—The paper read was "*On the Periodical Alternations and Progressive Permanent Depression of the Chalk Water Level under London.*" By the Rev. J. C. Clutterbuck.

The author began by defining the Chalk Water level to be, "the height to which the water rises at any point or continuous series of points in the chalk, or *from* the chalk in perforations, through the London and plastic clays, above the chalk." The term 'Artesioid' was used to describe those wells sunk through the London and plastic clays, in which the water rose from the chalk, or the sands of the plastic clay formation, above the level of those strata, though it might not rise to, or overflow the surface of the ground.

Reference was made to papers read before the Institution in 1842 and 1843, in which it was shown that the chalk water level was described by an inclined line drawn from the highest level at which the water accumulated in the chalk, to the lowest proximate vent, or outfall: a general rule, which was found to hold good, not only where the water was found by sinking into a permeable stratum, but where, as in the London Basin, the water rose from a permeable stratum, through perforations in any impermeable stratum above it.

The example treated of in the paper, was described by a line inclining at an average of about 13 feet in a mile, from the outcrop of the London and plastic clays, to mean tide level in the Thames, below London Bridge.

The height to which water rose in the Paris Basin, from the lower green sand, was adduced in confirmation of that rule. Before the artesian well at Grenelle was bored, M. Arago calculated, that the water would rise above the level of the soil at Paris, as it rose above that level at Elbeuf, near Rouen. The height at which the water was found in the lower green sand, near Troyes, being 100 metres above Paris, and 131 metres above the sea, the author found that a line drawn from that point, to the level of the sea at Havre (where the green sand cropped out), passed over Paris and Elbeuf at the elevation to which the water actually rose in both places. A calculation based on the same principle (taking the level of the water in the lower green sand, at Leighton Buzzard, at 280 feet above the sea), showed that if the chalk and gault were bored through in London, the water from the green sand would rise 150 feet above Trinity high-water mark.

Passing from the natural to the actual condition of the chalk water level, under London, there was a general permanent depression of from 50 to 60 feet below Trinity high-water mark. Measurements of a well in London, in which the level was seldom disturbed, showed periodical alternations, coincident with the exhaustion and replenishment of the chalk stratum by natural causes, to the amount of 4 ft. 6 in., and a permanent depression of 1 ft. 6 in. per annum, or 12 feet in eight years.

Again, referring to former calculations, it was shown that the margin of this depression was extending in a greater ratio towards the North than to the South, or S.E. Since 1843, the level was permanently depressed at Hampstead-road, 10 feet; Camden Town, 19 feet; Kilburn, 20 feet; and Cricklewood, 10 feet. The limit of the depression being, in 1843, between the latter places.

Allusion was then made to the influx of water at the point where the Thames passed over the outcrop of the sands of the plastic clay formation, and the chalk, as a point to be determined by geological inquiry, and connected with observations as to the action of the tides on the level, and the chemical quality of the water, in that neighbourhood.

The general conclusion drawn from all these facts was, that the rapidity of exhaustion from Artesian wells under London, greatly exceeded the rapidity of supply; that the amount of defalcation was marked, and could be measured by the extension of a progressive permanent depression, proving that the supply of water from the chalk stratum became each year more precarious, and less to be depended upon, even should there be no addition to the Artesioid wells in and around the metropolis.

In the discussion which ensued, it was shown that only such a supply of water percolated annually through the chalk stratum, as could be accounted for by the discharge from the rivers of the upper district. The results yielded by Dalton's Rain Gauge, as used by Mr. John Dickinson, were adduced in proof of this position.

The chemical analysis of water from wells sunk into the chalk, showed the probability of an influx of the tidal water of the Thames, to replenish the vacuum caused by the immense extent of pumping from the London wells.

On the other hand it was contended, that from the great extent of surface whence the chalk derived its supply, there might be such a surplus store of water, as would warrant any amount of pumping, for the domestic supply for the metropolis.

ROYAL SCOTTISH SOCIETY OF ARTS

Dec. 10, 1849.—Thomas Grainger, Esq., C.E., President, in the Chair.

The following communications were made:—

1. The President delivered an address on the desirableness of obtaining communications relative to the Construction and Details of Engineering and other Public Works, accompanied by the necessary Models and Drawings.

2. "*Notice of a Chromatic Stereoscope.*" By Sir David Brewster, K.H., F.R.S., V.P.R.S.E.

The instrument consists of one lens 2½ inches in diameter or upwards, through the margin of which each eye looks at an object having *two* colours of different refrangibility. The effect of this is to cause the two parts of the object thus differently coloured, to appear at different distances from the eye, just as in the *Lenticular Stereoscope*, the two parts of an object that are nearest to one another in the double picture rise in relief, and give the vision of distance as of a solid figure. The instrument may consist of two semilenses, convex or concave, or of two prisms with their refracting angles placed either towards or from one another; and the effect is greatly increased if the lenses or prisms have high dispersive powers, such as flint glass or oil of cassia.

NOTES OF THE MONTH.

RAILWAYS OPENED IN THE YEAR 1849.

The aggregate length of English railways opened for traffic in the year 1849 was 750 miles; of Scotch railways 73½ miles, and of Irish railways 114 miles—making the aggregate length of railways opened in the United Kingdom during the past year 937 miles, being 270 miles less in extent than those opened during the year 1848.

The English lines were—

Chester and Holyhead, Mold branch, 13¾ miles.
East Anglian, 24 miles.
East Lancashire, 45 miles.
Eastern Counties and Norfolk, 15 miles.
Eastern Union, including the Stour Valley line, 43 miles.
Furness, 17½ miles.
Great Northern, 33 miles.
Great Western extensions, 30 miles.
Lancashire and Yorkshire branches, 12 miles.
Leeds and Thirsk, 30 miles.
London and Blackwall, 1¾ mile.
London and North-Western (Huddersfield and Manchester, and Leeds and Dewsbury), 44 miles.
London and South-Western branches, 22¾ miles.
Manchester, Buxton, Matlock, and Midland, 12 miles.

Manchester, Sheffield, and Lincolnshire branches and extensions 97 miles.
Midland extension, 16 miles.
Newcastle and Carlisle branch, 4 miles.
North Staffordshire, 51¼ miles.
North-Western, 37 miles.
Reading, Guildford, and Reigate, 45 miles.
Shrewsbury and Birmingham, 30 miles.
Shropshire Union, 30 miles.
South Devon, 2¼ miles.
South-Eastern (North Kent), 25¾ miles.
South Staffordshire, 17¾ miles.
South Yorkshire, 9 miles.
Whitehaven and Furness, 16½ miles.
York, Newcastle, and Berwick branch, 21½ miles.

The Scotch lines were—
Aberdeen, 32 miles.
Caledonian extensions, 18 miles.
North British branches, 23¼ miles.

The Irish lines were—
Cork and Bandon, 9¾ miles.
Dublin and Belfast Junction, 22 miles.
Dundalk and Enniskillen, 18 miles.
Great Southern and Western extension to Cork, 58¼ miles.
Newry, Warrenpoint, and Rostrevor, 6 miles.

RAILWAY TRAFFIC, 1849.

The gross traffic receipts of railways in the United Kingdom for the year 1849 is estimated at 11,013,820*l.* on 5,161 miles of railway, being an increase of 954,820*l.* in the receipts over those of the preceding year on 4,326 miles, and also an increase of 835 miles of railway in operation.

Independent of these railways, there are about twenty new lines in operation, of an aggregate length of 445 miles, the traffic returns on which are not published weekly, but may be estimated at 200,000*l.* for the past year. In addition to these, there are fifteen other lines, of an aggregate length of 344 miles, belonging to old railway companies, who do not publish their traffic returns; but it appears from the returns to the Railway Commissioners that the gross receipts on these lines are about 470,000*l.* per annum. These sums, added to the above, show that the gross traffic receipts on all the railways in the United Kingdom during the past year amounted to 11,683,800*l.*; and the aggregate length of railway open and over which the traffic was carried was 5,950 miles, being at the rate of 1,963*l.* per mile per annum.

With regard to the traffic returns of the railways in Great Britain and Ireland, published weekly, they show a progressive increase during the past eight years as follows:—

	£		£
1842	4,341,788	1846	7,689,870
1843	4,842,650	1847	8,975,671
1844	5,610,980	1848	10,059,000
1845	6,669,230	1849	11,013,820

The annual increase in the receipts has been very considerable, partly arising from the continual development of the traffic on the trunk lines, and partly from the additional receipts derived from the opening of new lines and branches. The increase of traffic in the year 1843 over that of the preceding year amounted to 500,870*l.*; in the year 1844, to 768,337*l.*; in 1845, to 1,058,340*l.*; in 1846, to 1,020,650*l.*; in 1847, to 1,285,780*l.*; in 1848, to 1,083,335*l.*; and in 1849, the increase over the preceding year amounted to 954,810*l.*

At the end of the year 1842, 1,510 miles were open to the public; during the next year an additional length of 56 miles of new railway was opened for traffic; in 1844 a further length of 194 miles was opened; in 1845, 263 miles; in 1846, 593 miles; in 1847, 839 miles; in 1848, 975 miles; and in 1849, a further length of 834 miles, making at the end of the year a total length of 5,161 miles in operation.

The average traffic receipts per mile show the effect of opening within the past three years so many miles of branch and competing lines of railway. During the year 1842, the gross traffic receipts averaged 3,118*l.* per mile; in 1843, 3,085*l.*; in 1844, 3,278*l.*; in 1845, 3,469*l.*; in 1846, 3,305*l.*; in 1847, 2,870*l.*; in 1848, 2,336*l.*; and in 1849, 2,302*l.* per mile. This shows a gradual falling off in the average traffic per mile during three years of more than 30 per cent., and there seems every probability of its continuance, so long as the present erroneous system is pursued in constructing unproductive extensions and unnecessary branches. The reduction in the receipts per mile would be a matter of no great consequence, provided the average cost of constructing the railways was proportionably reduced, say in the same ratio of the traffic per mile, from 33,000*l.* to 23,000*l.* per mile, and so on in like manner with every additional mile added to the system. Unfortunately this is not the case, as the following will show:—In 1842 the cost of the railways in operation averaged 34,690*l.* per mile; in 1843, 36,360*l.*; in 1844, 35,670*l.*; in 1845, 35,070*l.*; in 1846, 31,860*l.*; in 1847, 31,700*l.*; in 1848, 34,234*l.*, and in 1849, 35,214*l.* On a comparison of the average cost per mile in 1845 of 35,070*l.*, when there were only 2,040 miles of railway open, with the average cost in 1849, of 35,214*l.*, when there were 5,160 miles open, it shows that an increase in the cost per mile has taken place, notwithstanding that 3,120 miles of additional railways and branch railways have been constructed.

The increase instead of a decrease in the average cost per mile is a most alarming feature in railway statistics, because it shows clearly that the continual additions to the capital accounts of the old and completed lines of railway far outweigh all the professed advantages of constructing thousands of miles of new railways and branches at considerably less cost than the average expenditure per mile on the old trunk lines. It was stated both in and out of Parliament that the new lines authorised in the 1844 and succeeding sessions would not exceed 25,000*l.* per mile, and that a considerable portion of them would not cost above 18,000*l.* per mile. Some have been constructed within the estimate, and others have exceeded it. The serious evils arising from the improper practice of adding large sums every half-year to the capital accounts of old railways must be remedied in future by closing at once their capital accounts, and also the capital accounts of every new railway, before the end of two years after the opening of the line; otherwise there can be no foundation for confidence in either railway property or railway management.

The capital expended on railways, the traffic returns of which are published every week, amounted in July 1842, to 52,380,000*l.*; in 1843, to 57,635,000*l.*; in 1844, to 63,489,000*l.*; in 1845, to 71,648,000*l.*; in 1846, to 83,165,000*l.*; in 1847, to 109,528,000*l.*; in 1848, to 148,200,000*l.*; and in July 1849, to 181,000,000*l.* The gross traffic returns per cent. on the capital expended amounted, in 1842, to 8·29 per cent.; in 1843, to 8·42; in 1844, to 8·84; in 1845, to 9·30; in 1846, to 9·25; in 1847, to 8·20; in 1848, to 6·78; and in 1849, to 6·13 per cent. This gradual decrease in the revenue, with a greatly increased capital and mileage, shows the absolute necessity of closing the capital accounts.

The expenditure on the new and old lines, the traffic returns of which are not published weekly, amounts to about 16,000,000*l.*, that is, 9,000,000*l.* on the former, and 7,000,000*l.* on the latter, making, with the 181,000,000*l.*, a total of 197,000,000*l.* expended on 5,950 miles of railway, being an average cost of 33,110*l.* per mile.

PROTECTION OF IRON FROM OXIDATION.

At the Exposition at Paris in 1849, there were exhibited numerous articles manufactured in iron, covered with a kind of transparent vitreous coating, completely spread over the surface of the metal, like a varnish, and capable of affording a perfect protection against the action of the air, or any other oxidizing agent. This appears to be an invention susceptible of many useful applications; for, whether the iron be in the state of a rolled plate or bar, or drawn into tubes; whether it be cast into water pipes or into articles of the most elaborate form and design, as vases, and other ornamental works, it can be equally well endowed with this protective coating—it is also a matter of indifference whether the article be made of forge or cast-iron. The following is stated to be the process employed in imparting to the iron the vitreous surface:—Firstly, the object, whatever its shape may be, is thoroughly cleansed by dilute acid, which serves to remove, from the metallic surface, grease, dirt, and every trace of oxide; this is important, for, if any foreign matter remain upon the surface, the perfect adherence of the fused glass will be effectually prevented, when that part of the operation is reached. After the action of the dilute acid, the work is to be well washed and then dried; when perfectly dry, it must be brushed over with a tolerably strong solution of gum-arabic, which may be applied by means of a camel-hair brush. Over the whole extent of the gummed surface, powdered glass, of a peculiar kind, is then sifted, and care must be taken to cover every part of the surface with this powder, otherwise the vitreous coating will be imperfect when the operations are completed. When thus prepared, the work is introduced into a furnace or retort, heated to 100° or 150° centigrade; (212° to 302° F.) and, when thoroughly dry, it is removed to another furnace, where it is brought to a cherry-red heat; the vitreous matter, which adhered to the gummed surface of the metal, now undergoes fusion—the progress of this stage of the process is ascertained by looking through a small opening (contrived for this purpose) into the heated chamber. When the fusion is complete, and the glass seems to have flowed over the whole of the surface, the article is removed from the furnace and placed in a close chamber, from which the air is entirely excluded—here it is kept until it has cooled down to the temperature of the atmosphere. The vitreous compound, applied to the surface of the metal, consist of the following substances:—Powdered flint glass, 130 parts; carbonate of soda, 20½ parts; boracic acid, 12 parts. These must be melted together in a "glass pot," and a fusible glass will be the result; when cold, this must be pounded with care, so that it may be reduced to a powder, sufficiently fine to pass through a silk sieve. When thus prepared, it is ready to be applied to the surface of the iron, according to the method described above. If, after the first process, the coating of vitrified matter on the metal should prove not to be quite perfect, the manipulation must be repeated, a second coat of powdered glass being applied in the same manner as the first. It is necessary that the vitreous matter which forms the coating should be quite free from foreign matter, for if the object to be coated be oxidised or greasy, the coating of glass will not adhere, and the result of the operation will be, consequently, very imperfect.

Tracing Paper.—Messrs. Waterlow and Sons have recently introduced a very useful description of French tracing paper for the Engineer's office. It is to be had 40 inches wide and 21½ yards in length, and is remarkably transparent.

Assyrian Antiquities.—Major H. Rawlinson, the E.I.C.'s Political Agent in Turkish-Arabia, and H.M.'s Consul at Bagdad, who has lately arrived in this country from Bagdad, has brought with him a quantity of casts of Babylonian inscriptions, and also some packages containing figures of stone and terracotta, being remains of Assyrian antiquities; and they are intended to be deposited in the British Museum and other scientific institutions of the metropolis. Lord Mahon exhibited some of the casts at the Society of Antiquaries on the 24th ult.

Testimonial to Mr. Dockray, Resident Engineer on the North-Western Railway.—As a testimonial of respect for his well-known and uniform integrity of character, Mr. Dockray has had the proud gratification of being presented by his brother officers in the London and North-Western Railway, and by other gentlemen professionally connected with him, with a half-length portrait of himself, painted by Phillips, accompanied by a purse of 60 sovereigns, and 500*l.* of London and North-Western Stock at par. Mr. Dockray was, moreover, presented at the same time with an elegant silver service of plate, of the value of 198*l.* Both portrait and service bear the following inscription:—"This service of plate, together with this portrait, and 500*l.* London and North-Western Railway stock, was presented to Robert Benson Dockray, Esq., M.I.C.E., resident engineer of the London and North-Western Railway, by 700 subscribers, consisting of his brother officers, and private friends, as a testimonial of their respect and esteem, November, 1849." The portrait has been engraved in a most masterly style by T. L. Atkinson, Esq.

East India Railways.—Mr. J. C. Melvill, the secretary of the East India Company, has been appointed the ex officio director of the India Railway Companies, in pursuance of the Acts and the respective contracts with these bodies, and three engineers have been chosen by the East India Peninsular Company to go out to Bombay, for the purpose of proceeding at once with these works. The gentlemen selected are Mr. J. Berkeley, formerly a pupil of Mr. R. Stephenson, and subsequently a sub-engineer on the North Staffordshire line; Mr. C. Ker, resident engineer, under Mr. Locke, on the Aberdeen line; and Mr. Graham, a nephew of Sir James Graham, and a pupil of Mr. Stephenson.

Monster Pontoon at New Holland.—Another great step has been taken to bridge across the Humber. A floating island, half an acre in extent, has been launched into the sea. This island is formed wholly of iron plates, in the form of a rectangular pontoon; and floats at the end of the pier of the Manchester, Sheffield, and Lincolnshire Railway station, opposite Hull. The pontoon is connected with the pier by means of two tubular platforms or bridges, which always afford an easy descent, and the passengers alight from the carriages and walk under cover to the boats, which convey them in ten minutes, at the rate of fifteen miles an hour, across the ferry. This pontoon is part of the great system of railway ferries designed by Mr. Fowler for the Hull station, the successful and complete carrying out of which is a principal condition of the success of the railway, which it connects with its most populous eastern terminus. The great mass was launched on the 4th ult., with perfect success—and on going into the water floated at the exact line marked out for it, thus proving the accuracy of the previous calculations of the engineer. It was constructed by Messrs. Wilson and Co., of Leeds, as contractors, under the immediate superintendence of Mr. Ikin, and it is an excellent piece of workmanship, as well as a most successful engineering design.

New Peninsular Steam-Fleet.—We understand that, in anticipation of securing the contract for conveying the mails between India and Australia, and of performing the whole of the Mediterranean and Bombay service, the Peninsular and Oriental Company have determined on building seven new and powerful paddle-wheel steam vessels. Todd and Macgregor, of Scotland, are to build two of the number, they having succeeded so well with the Sultan, the ship last built. The vessels are to be built of iron.

Navigation of the Ganges.—An iron steam vessel is now being built by Mr. J. Laird, of Birkenhead, intended for the navigation of the Ganges. She is 200 feet long, and 30 feet beam, and will only draw, when loaded, about two feet of water. The form is that of the canoe, shovel-shaped at both extremities, and the bottom, amidships, without keel, forming an inverted gentle segment of an arch; the centre portion, however, or floor, being nearly flat. The rudder is applied at either end, as necessity requires. The vessel is divided longitudinally, into three parts, by tight bulkheads; and traversing these, there are other bulkheads, dividing the whole vessel into 30 water-tight compartments, and adding greatly to her strength. The vessel, which is for the East India Company, will, when finished, be taken to pieces, and sent in a ship to India, to be finally put together.

Mineral Veins.—MM. Malaguti, Durocher, and Sarzeaud, announce that they have detected in the waters of the ocean the presence of copper, lead, and silver. The water examined appears to have been taken some leagues off the coast of St. Malo, and the fucoidal plants of that district are also found to contain silver. The F. serratus and the F. ceramoides yielded ashes containing 1-100000th; while the water of the sea contained but very little more than 1-100000000th. They state also that they find silver in sea salt, in ordinary muriatic acid, and in the soda of commerce; and that they have examined the rock salt of Lorraine, in which also they discover this metal. Beyond this, pursuing their researches on terrestrial plants, they have obtained such indications as leave no doubt of the existence of silver in vegetable tissues. Lead is said to be always found in the ashes of marine plants, usually about an 18-100000th part, and invariably a trace of copper. Should these results be confirmed by further examination, we shall have advanced considerably towards a knowledge of the phenomena of the formation of mineral veins.

Improved Drilling Machine.—Mr. M. P. Coon, of Lansingburgh, New York, has taken out a patent for a new stone drilling machine, by which the drill can be worked not only perpendicularly, but horizontally, and at any angle within the plane of a semicircle. This arrangement is effected by the employment of spiral springs, so arranged that they are negative—that is, they are of sufficient power of contraction and extension to counteract, or counterbalance, more than the entire gravitating power of all the machinery required to raise the drill shaft. Upon the same principle, a concussive power is obtained and counteracted; and, consequently, the drill shaft may be worked with any amount of concussive power, and at any angle required. They are constructed of any required size. The drill shafts, weighing from 10 to 1000 lb., will drill any size hole, from ½ in. to 2 ft. diameter; and the concussion, or blow, for cutting the rock, is wholly regulated by the weight of the drill and the height from which it falls. A Mr. Jack, of Maine, has also taken out a patent for working a drill by springs; but which is the original idea, or whether they are identical or otherwise, we have no means of ascertaining.

Burning Water instead of Lamp Oil.—The *New York Sun* has a letter from Worcester, Massachusetts, in which the writer claims to have invented and put in use an apparatus which separates the oxygen of which water is composed, and produces gases for lights. This it does at no other expense than that of the machinery, as no material but that of water is used. The water is decomposed by a current of electricity, evolved by the apparatus. The labour of five minutes, once in two hours in the day, in winding up the machine, is all that is required to produce 250 cubic feet of gas. The expense of the machine is 300 dollars, and it can be carried by a man under his arm. Such is the description of it—time will determine whether it is even so.

LIST OF NEW PATENTS.

GRANTED IN ENGLAND FROM DECEMBER 21, 1849, TO JANUARY 24, 1850.

Six Months allowed for Enrolment, unless otherwise expressed.

Louis Cesaires Charpillion, of Rue de Luxembourg, France, for improvements in locks for guns, and pistols.—December 29.

John Read, of Park-terrace, King's-road, Chelsea, for improvements in machinery for extracting fluids from animal, vegetable, and mineral substances, and in compressing the same.—December 29.

William Palmer, of Sutton-street, Clerkenwell, Middlesex, manufacturer, for improvements in the manufacture of candles, lamps, and wicks.—December 29.

William Barlow, of Blackheath, civil engineer, and William Henry Barlow, of Derby, civil engineer, for improvements in the permanent ways of railways.—January 3.

Albert Crackell Waterlow, of London-wall, lithographer, for obtaining copies of writings, drawings, and other designs. (A communication.)—January 3.

Alexander Brodie Cochrane, Jun., and Archibald Slate, of Dudley, Worcester, engineer, for improvements in the manufacture of iron pipes or tubes.—January 3.

Thomas Lightfoot, of Broad Oak, within Accrington, Lancaster, chemist, for improvements in printing and dyeing fabrics of cotton and of other fibrous materials.—January 3.

William Buckwell, of the Artificial Granite Works, Battersea, civil engineer, for improvements in compressing or solidifying fuel.—January 3. To extend to the Colonies only.

Joe Sidebottom, of Pendlebury, Lancaster, manager, for certain improvements in steam engines.—January 3.

Henry Dorning, of Hearsley, near Bolton, Lancaster, brick and tile manufacturer, for certain improvements in machinery or apparatus for manufacturing bricks, tiles and other similar articles from clay or other plastic materials.—January 3.

David Blair White, of Newcastle-upon-Tyne, doctor of medicine, for an improved mode of ballasting and stowing cargo in ships and other vessels.—January 8.

Matthew Urlwin Sears, of Burton-crescent, St. Pancras, Middlesex, commission agent, for the improved construction of guns, and cannons, and manufacture of cartridges for the loading or charging thereof.—January 11.

Samuel Newington, of Knole, Frant, Sussex, doctor of medicine, for improvements in sowing, manuring, and cultivating land, and of certain of the implements used therein.—January 11.

Bennett Alfred Burton, of the firm of Bennett, Burton, and Burton, of John's-place, Holland-street, Southwark, engineer, for certain improvements in apparatus connected with sewers, drains, and cesspools, also in suction and delivery pipes, and in connecting such pipes or hose; the apparatus connected with sewers, drains, and cesspools being applicable to other like purposes.—January 11.

John Fayrer, of Surrey-street, Strand, commander in Her Majesty's Navy, for improvements in steering apparatus.—January 11.

Alfred Cooper, of Romsey, Hants, grocer, for improvements in steam and other power engines, and in the application thereof to motive purposes; also in the methods of, and machinery for, arresting or checking the progress of locomotive engines and other carriages.—January 11.

James Macdonald, of Chester, coachmaker, for certain improvements in the method of applying oil or grease to wheels and axles, and to machinery; and in connecting the springs of wheel carriages with the axles or axle-boxes.—January 11.

John Glasgow, of Manchester, engineer, for certain improvements in machinery or apparatus for shearing, shaping, punching, and compressing metals.—January 12.

John Milwain, of Manchester, joiner, for certain improvements applicable to the closing of doors, windows, and shutters.—January 12.

Andrew Barclay, of Kilmarnock, North Britain, engineer, for improvements in smelting of iron and other ores, and in the manufacture or working of iron and other metals, and in certain rotary engines and fans, machinery, or apparatus connected therewith.—January 15.

Richard Smith, of Clitheroe, Lancaster, manufacturer, for certain improvements in looms for weaving.—January 17.

Henry Cowing, of Stamford-street, Blackfriars, gentleman, for improvements in obtaining motive power, and in steam and other ploughs, in land carriages, in fire-engines, in raising water for draining and other agricultural purposes, and in apparatus for evaporating saccharine and other liquors.—January 17.

Joseph Nye, of Mill-pond Wharf, Park-road, Old Kent-road, engineer, for improvements in hydraulic machinery; parts of which machinery are applicable to steam-engines and machinery for driving piles.—January 17.

William George Henry Taunton, of Liverpool, civil engineer, for certain improvements in obtaining motive power, and in a means to ascertain the strength of chains and ships' cables.—January 17.

Robert Barbor, of Chatham-place, Lock's-fields, Surrey, metal melter, for certain improvements in artificial fuel, and in machinery used for manufacturing the same.—January 17.

Macgregor Laird, of Birkenhead, gentleman, for improvements in the construction of metallic ships or vessels, and in materials for coating the bottoms of iron ships or vessels, and in steering ships or vessels.—January 19.

William Beadon, jun., of Taunton, Somerset, gentleman, for improvements in conveying away or decomposing smoke and products of combustion from stoves or grates, and in ventilating rooms of residences.—January 19.

George Simpson, of Buchanan-street, Glasgow, civil and mining engineer, for a certain improvement or improvements in the machinery, apparatus, or means of raising, lowering, supporting, moving, or transporting heavy bodies.—January 19.

William Wood, of Over Darwen, Lancashire, carpet manufacturer, for improvements in the manufacture of carpets, and other fabrics.—January 23.

Christopher Nickels, of York-road, Lambeth, Surrey, gentleman, for improvements in the manufacture of woollen and other fabrics.—January 23.

Walter Westrup, of Wapping, Middlesex, miller and biscuit baker, for improvements in cleaning and grinding corn or grain, and in dressing meal or flour.—January 24.

Auguste Reinhard, of Leicester-street, Leicester-square, Middlesex, chemist, for improvements in preparing oils for lubricating purposes, and in apparatus for filtering oil and other liquids.—January 24.

Joseph Long and James Long, of Little Tower-street, London, mathematical instrument makers, and Richard Pattenden, of Nelson-square, Surrey, engineer, for an improvement in instruments and machinery for steering ships, which is also applicable to vices, and other instruments and machinery for obtaining power.—January [illegible]

LECTURES ON ARCHITECTURE,

By Samuel Clegg, Jun., Esq.;

*Delivered at the College for General Practical Science, Putney, Surrey.**

(PRESIDENT, HIS GRACE THE DUKE OF BUCCLEUCH, K.G.)

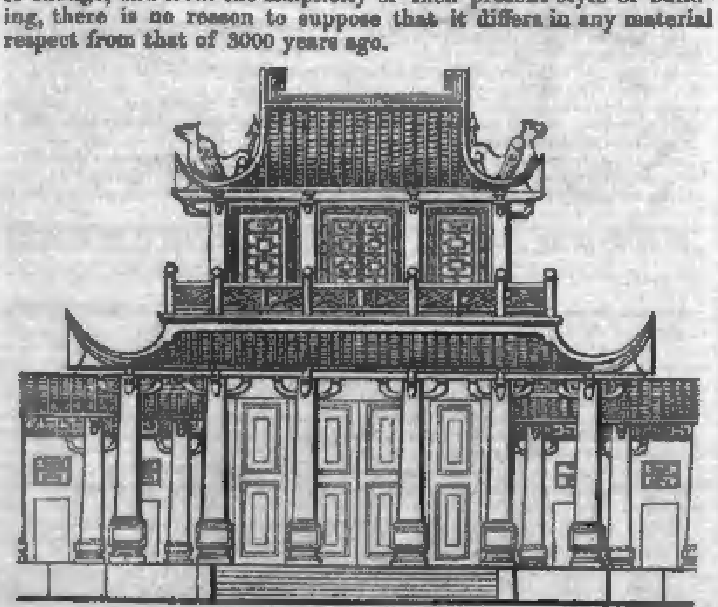
Lecture III.

China.—Central America.—Celtic remains.

We have hitherto been following the traces of the Agriculturist: in approaching China, we come upon the footsteps of the Pastoral tribes, the dwellers in tents,—amongst whom any great progress in the science of Architecture may be looked for in vain.

As it will not be necessary again to refer to China in the course of these Lectures, I must be allowed, instead of confining myself to an historical period, to speak of the architecture of this singular country as it exists at the present day; thus substituting distance of place for distance of time.

In China, the adherence to the original type of the tent is everywhere apparent: their pagodas and towers resemble a number of tents placed one over another, instead of side by side; the houses of the mandarins chiefly differ from those of the lower orders by covering a greater extent of ground; and the palace of Pekin is merely like a camp within an outer encampment, formed by the tent-like houses of the city. Owing to the frailness of material and peculiarly slight style of building, it is not likely that the Chinese edifices could long resist the devastating march of time; indeed, it is supposed that with the exception of the Great Wall, and perhaps a few pagodas, no building exists in that country more than 300 years old. Any description of the ancient architecture of China would, consequently, be merely conjectural. But from the religious and political thraldom to which the Chinese are subjected, from their natural repugnance to change, and from the simplicity of their present style of building, there is no reason to suppose that it differs in any material respect from that of 3000 years ago.



Elevation of Chinese House.

Timber, crude and burnt brick are the materials most in use; the bamboo, which in China grows to a remarkable height and size, is also employed. Stone and marble are rare, and are only partially used even in the public buildings and tombs. The characteristics of Chinese architecture are extreme lightness and gaiety of effect, the tent-like form, the coloured and varnished roofs, and variously-tinted walls—giving, as Sir William Chambers observes, "a pretty and toy-like appearance" to their buildings. The height and size of each dwelling-house must be in exact accordance with the caste of the proprietor; and even the details are regulated by law. A mandarin, who had ventured to erect a mansion of superior elegance, was summoned before the emperor to answer for his presumption; and thought it wise to raze the obnoxious structure to the ground, in order to avert fine or other punishment.

The roofs of the Chinese buildings are convex in their sides, spine, and ribs, presenting the appearance of a pliant material; they are supported by wooden columns without capitals, having, instead, ornamental consoles projecting from the sides, which give additional support to the verandah. The roofs turn up at the eaves, and are finished with a spike, like the hook or fastening of a tent; and this part is frequently decorated with the figure of a dragon, which is the national emblem. The wooden columns being the main support of the roof, the side walls are very slight. The window frames are filled-in with open rectangular patterns, intersecting each other; the railwork of the balconies and verandahs is formed in a similar manner. The interior walls are gaily ornamented with variegated matting, and painted paper or silk. Sometimes, in the upper stories, the partition walls are partly formed of cane trellis-work covered with painted gauze, admitting light and air. The aperture leading from one room to another, or from the corridor to the garden, is frequently a lunette, a circular opening, instead of a rectangular doorway, giving a picture-like effect to the vista beyond. As these round doors are considered lucky, the evil spirit not being supposed to be willing to enter by them, there is always one at least of this form in every Chinese building. The gardens are cultivated with great taste and skill.

The houses of the lowest class are miserable and poverty-stricken, being nothing more than mud or crude brick huts, and covered with straw or rushes. The farm-houses are not much better, having generally a mud floor, and the apartments frequently being only separated by mats hung from the ceiling. The custom of plastering the inferior kind of houses with mud gives them a dingy appearance. Lime is a scarce commodity in the country, the only kind being prepared from shells and stones cast up by the sea.

The cities of China are by no means imposing in effect, as the surrounding walls are higher than the buildings they inclose—the Taas or towers being the only lofty structures. These towers are formed of several tent-like stories, diminishing in size as they ascend; and they are gaudily decorated, and hung with little tinkling bells at each angle of the many roofs.

The celebrated porcelain tower at Nan-king is of nine stories, forming a height of 216 feet; the roofs are covered with pale green glazed tiles, whence it derives its name. The pagodas are surrounded by courts and vestibules, the cells of which serve as a residence for the priests or bonzes. The Chinese have a great taste for gay and fanciful decoration: the glazed tiles of the roof are frequently arranged in the form of fishes' scales, and the pavements occasionally formed of shells laid in a pattern like mosaic-work. The timbers of the roof, which are always left exposed, are, in the habitations of the higher castes, formed of costly woods, or inlaid with ivory and mother-of-pearl.

As engineers, the Chinese were skilful in very early times; their bridges and canals bear as ancient a date as those of any of the great eastern nations, and that they were not ignorant of the art of building in its most solid and imperishable form, the Great Wall remains to testify. This stupendous undertaking separates China from Northern Tartary, and was completed about 214 B.C.; its length is computed at about 1500 miles; and a curious calculation has been made, that the materials of this wall, including the earth-work, would be sufficient to surround the world with two walls each six feet high and two feet thick. It is said that every third man in the kingdom was summoned to assist in its construction. It pursues a direct course over hill and valley, passing the rivers on arches; the only interruption is a ridge of lofty mountains in the province of Pe-tche-lee, and the broad river Hoang-ho. The foundation is formed of large stones laid in mortar; upon this is raised a mound of earth, cased in some places with brick, in others with stone. On the elevated ground it is only from 15 to 20 feet high, but along the valleys it is raised to the height of 30 feet. It is paved on the top with flat stones and is wide enough for six horsemen to ride abreast. In the valleys, and those places most open to attack, projecting towers are constructed within bow-shot of each other. Notwithstanding the enormous extent of this wall, it is said to have been finished in five years.—The Imperial or Grand Canal is a work of nearly equal magnitude, traversing a length of 900 miles.

There is so very little really interesting or instructive in Chinese architecture, that I shall pass on without further notice of it.

The countries of which mention has hitherto been made are contiguous, or nearly so, so that mutual intercourse and interchange of ideas has aided the progress of civilisation: I have now to speak of a far-off country, and to describe ruins that lie amidst the forest and jungle till lately unknown and unthought of, unless in the dreams of the poet.

"Man was in ancient days of grosser mould,
And Hercules might blush to learn how far
Beyond the limits he had vainly set,
The dullest sea-boat soon shall wing her way;
Man shall descry another hemisphere.
* * * * * *
At our antipodes are cities, states,
And thronged empires, ne'er devined of yore."
—'Morgante Maggiore.'

Thus sang Pulci, while Columbus was either yet unborn or in his childhood, sailing toy boats on the bay of his native Genoa. Rumours had from time to time been afloat, of ruined cities in the midst of the trackless woods of Western and Central America; hunters and travellers had found masses of masonry and sculptured stones half hidden beneath the roots of the many-wintered giants of the forest: but these reports were long treated as travellers' tales, or as the result of a vivid imagination mistaking some curiously-shaped stone for the work of man's hand, where it was supposed man had never been. At last, exactly one hundred years ago, a party of Spaniards travelling in Central America, found unmistakeable ruins; and on examination, hewing their way through the dense forest, discovered the remains of a city, extending over 18 or 20 miles.

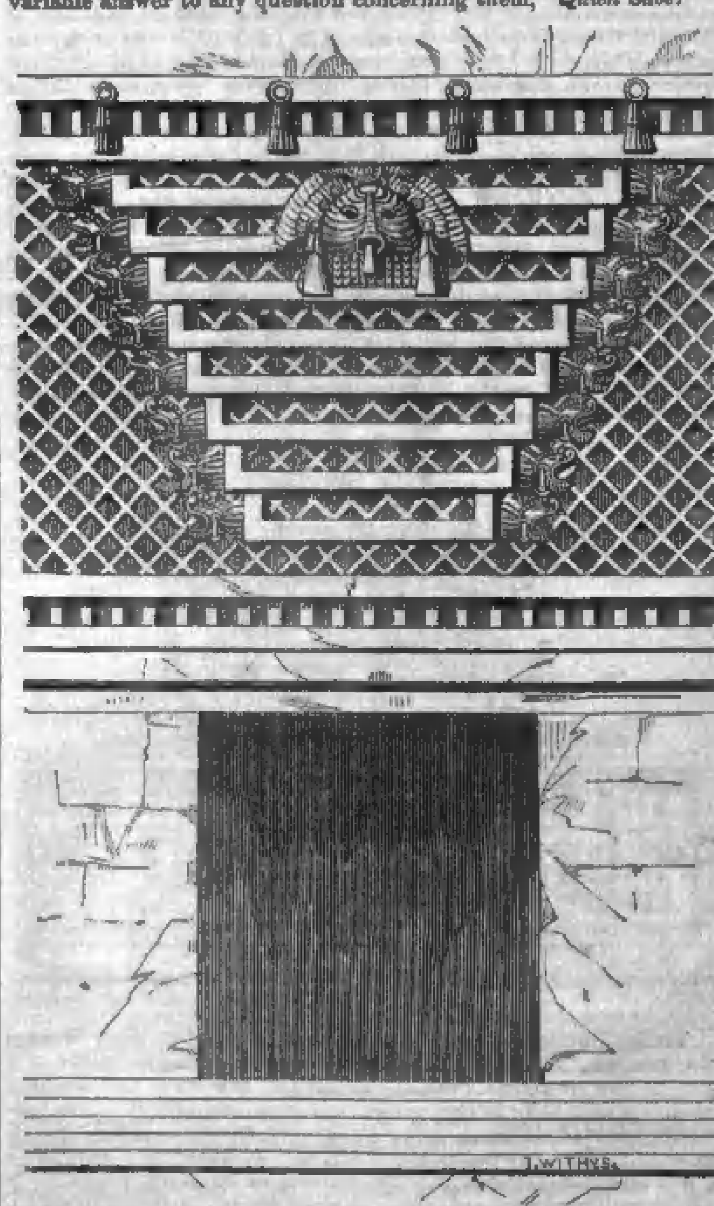
An exploring party was then sent out by the King of Spain in 1786, but either through jealousy or indifference, their report remained unpublished until the papers fell into the hands of an English gentleman at Guatimala, during the revolution of 1822. Still, doubts were thrown upon the authenticity of this narrative, and little interest was excited, until a paper appeared in the *Literary Gazette* in 1831, calling the attention of the public to the discoveries of Colonel Galindo; by this time, also, the celebrated Von Humboldt had travelled in Central America, and when his researches were published, scepticism was compelled to give way. Since then, many travellers have explored the country, and new discoveries have been made by Messrs. Stephens, Catherwood, Waldeck, and others; and already forty-four ruined cities have been brought to light in Yucatan alone.

Naturally, where no certainty exists, each discoverer erects his own theory as to the date of this lost empire, and the race by which it was inhabited. At present, the most generally received opinion is, that these ruins are not so ancient as those of the Eastern world, and that they were living cities at the time of the Spanish conquest. The historian, Herrera, who accompanied Cortes in his expedition against Mexico, describes the natives as having a peculiar form of head, such as is represented on the sculptures, probably flattened back during infancy; and speaks of lofty terraces, ascended by flights of steps; of temples, magnificent palaces, and carved idols, all of stone. It is to be presumed, however, that as in our own quarter of the globe, cities fall into decay, while others rise in their neighbourhood, so in America some of the remains may be of a date anterior to others: the architecture of Palenque, for instance, appears to belong to an earlier period than that of Uxmal; and at the time of the conquest, though the Spaniards paused to erect a cross within two or three miles of Palenque, no mention is made of a populous city in the vicinity; most likely, therefore, it was already in ruins and hidden in the forest at the time they passed by.

Winged Globe.

The American Archæological Society have come to the conclusion that the first inhabitants were colonists from Tartary and Malacca; and it is thought they did not cross the ocean, but had wandered to the far north, and so overland to the new continent—successive races passing onwards, until they settled in the plains of Mexico and Yucatan. If this be the correct theory, it is singular how they could have supported themselves during their northern transit, and that they should have left no distinct traces of their footsteps by the way. Evidences of an Eastern origin are, however, not wanting: the winged globe is found over the doorways of Palenque, and the resemblance to the sacred symbol of Egypt is too exact to have been mere accident. Pyramids, too, and even mummies, have been found in Peru; and in the valley of the Ohio, tumuli have been found, containing conical domes of masonry, exactly the same as the "tholi" of the Pelasgians.

The rapid and rank growth of vegetation in that hot, damp climate may account for the state of utter ruin in which the most modern of these cities is found; but it is difficult to conceive (even allowing for the supineness of the Spanish Indians) how, in the course of a few generations, all record, all tradition of the past could so completely have disappeared: the hieroglyphics carved on the monuments are as utterly unintelligible to those whose great grandfathers must have spoken the same language, as are the Etruscan inscriptions after the lapse of nearly two thousand years. The only name the Indians have for the ruins, when even aware of their existence, is "*Casas de Piedras*," and the invariable answer to any question concerning them, "*Quien Sabe!*"

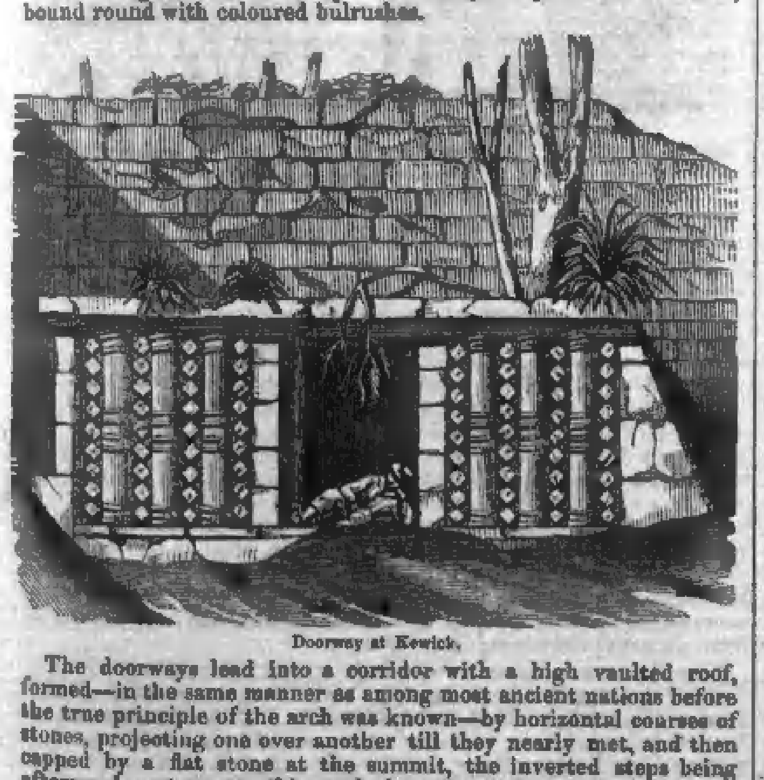


Portion of Façade from Casa del Gobernador.

In general appearance, the cities of Central America must have greatly resembled those of Assyria: like the Assyrians, this mysterious people built their temples and palaces upon high artificial platforms; those of America were of pyramidal form, ascended by wide flights of steps. At Uxmal, the platform upon which the principal building, called the Casa del Gobernador, is elevated is divided into three terraces, of the respective heights of 3, 20, and 19 feet; the lowest terrace is 600 feet in length, and the façade of

the building on the highest terrace 390 feet in length. The steps do not always ascend in a direct line from the ground to the principal entrance of the building, but sometimes the first terrace is ascended by steps to the northern side,—while to arrive at the second the lower terrace has to be traversed half-way round, the next flight of stairs being found to the south: whether this plan was adopted for greater security, or from an idea of giving greater importance to the temple or palace by difficulty of access, it is hard to say. Occasionally, figures of great size, sculptured in bas-relief, have been found at each side of the steps. The principal flight of steps at Zayi is 32 feet in width.

The different cities would seem to have formed one great kingdom, from the similarity in architecture and the close resemblance of the sculptures and hieroglyphic inscriptions. The buildings are of stone, sometimes of one story, sometimes of two or three; when this latter is the case, each story recedes from the one below it, so as to give a pyramidal form to the structure. The façade is perfectly plain up to the moulding that runs along the top of the doorway; above this it is elaborately ornamented with carved work relieved on a painted ground. The style of decoration being barbarous and fantastic, the drawing of a portion of the façade of the Casa del Gobernador may serve to give an idea of the style: the grinning Gorgon's head in the centre calls to mind some of those on the antique Etruscan bronzes. Sometimes no general design has been adopted, but the façade covered with a kind of sculptured mosaic. In one instance, at Uxmal, the front of the building is divided into compartments by a bas-relief representing huge serpents intertwined like a rope; the compartments are occupied by figures of idols and other devices. Traces of paint are always found, the colours used being the same as in Egypt and Assyria. The façade is pierced by a number of doorways—sometimes as many as fourteen along the front of the building. These doorways are generallly mere rectangular openings, without moulding or other ornament; but, occasionally, rows of small columns or pilasters, not exceeding 6 ft. 6 in. in height, form the piers separating them. These columns are usually plain, with a square abacus; but at Kewick, as shown in the accompanying engraving, the attached pillars are ornamented with a binding round the shaft —reminding us of the description of Assyrian palm-tree columns, bound round with coloured bulrushes.



Doorway at Kewick.

The doorways lead into a corridor with a high vaulted roof, formed—in the same manner as among most ancient nations before the true principle of the arch was known—by horizontal courses of stones, projecting one over another till they nearly met, and then capped by a flat stone at the summit, the inverted steps being afterwards cut away: this method need not necessarily have been borrowed from the East, but would present itself naturally to all early builders in stone.—This corridor leads to an open court, surrounded by various apartments; in some of these courts an unhewn upright stone is found, which is supposed to have been a "kebla," or stone of observation, and to mark the site of a sacred edifice.

At Chichen there is an apartment with a flat roof, divided by transverse beams and supported by massive square pillars, like the interior of an Etruscan tomb; but, generally speaking, the buildings of ancient America differ more in the extent and number of the courts and corridors, than in style and arrangement. The masonry is beautifully wrought, the stones frequently polished and accurately fitted, though in some instances a mortar of lime and sand has been used. Near Copan, a quarry has been discovered in the midst of the forest, where many hewn stones are lying as if just ready to be removed.

The people of the Western world do not seem to have paid the same attention to the abodes of the dead as the inhabitants of the East: no sculptured tombs are found, nor are there any excavations, notwithstanding the proximity of rocks. A sepulchral pit was discovered at Copan, containing pots of red earthenware, many of which, according to Colonel Galindo, were full of human bones. Dishes and vessels of pottery have been found amongst the various ruins, and also images of terracotta. The images and idols are disproportionate, and hideous in the extreme, and appear calculated to excite feelings of repugnance and horror in the minds of the worshippers, rather than any sentiment of reverence or admiration.

There is a belief current in Yucatan, that amongst the mountains, in a region inaccessible to the white man, a city still exists, inhabited by the aboriginal race; and now and then a daring adventurer is said to have ascended a rocky peak, whence the gleaming walls and palaces of the mysterious town are visible—but none who have ventured beyond have returned to tell the tale. As the Indians say, "*Quien Sabe!*" The subject is as yet in its infancy; a wide field is open for discovery! and notwithstanding the dreadful climate, and fatigues and hardships to be endured in that wild country, doubtless there are daring spirits willing to follow in the footsteps of those who have led the way; and in a few years much may be brought to light, and perhaps all present theories and conjectures superseded by others founded on a surer ground of evidence.

I now proceed to the examination of a class of monuments more immediately interesting to us, as many of the most perfect are found in our own country. I mean those known as Druidical or Celtic remains. Among all the memorials of the past which time has spared to us, none are more wonderful than these: they exist everywhere—not only where the Celto-Scythian tribes are known to have permanently settled, but in Italy, Greece, Asia Minor, China, Persia, India, Egypt, and even in America. These monuments also tend to confirm the supposition, that at some period a similarity of worship has prevailed over the known world. They may be divided into five classes—viz. 1st, The Cairn, or carnedd; 2nd, The Maen-hir, or upright stone; 3rd, The Cromlech and Dolmen; 4th, The Kist-vaen, or stone chest; and, 5th, The Circle of stones.

The *Cairn* is simply a heap of stones, sometimes piled up in memory of any particular event, as in the covenant between Jacob and Laban,—sometimes as a sepulchral monument. When the cairn is unaccompanied by an upright stone, it is a sign that an infamous person lies beneath. To cast a stone upon a grave is an ancient mark of abhorrence—the sepulchre of Absalom is nearly choked up by the number of stones that have been thrown there in detestation of his memory. The tumulus, or barrow, on the contrary, was the most honourable place of burial; the kings and great men lay within these mounds, with their armour and weapons beside them. Frequently numerous skeletons are found in one barrow, which would seem to have been the cemetery for the surrounding population. In some places, several tumuli or barrows are grouped together. The word "tumulus" is from the Celtic root *tumba*—whence *tombeau* and tomb; "barrow" is from the Saxon *beorg* or *byrig*, and is applied indiscriminately to any mound of earth, whether intended as a fortification or a place of sepulture. The termination "bury" is taken from this word; and near any of our numerous towns ending in *bury*, some ancient earthwork invariably is, or has been found. The custom of burying within these mounds or heaps continued for many centuries after the Christian era, for we find a law of Charlemagne, in the ninth century, enacting that the bodies of all Christians shall be taken to the cemeteries, and not buried in the tumuli of the heathens. Heaps of stones are also piled as landmarks; they are placed on the hills in Scotland to guide the shepherds, and still receive the name of cairns.

The *Maen-hir*, the stones of memorial or observation, were generally placed upright as pillars. This setting-up of stones was the most ancient manner of commemorating any important fact; Jacob, after his memorable dream, set up the stone on which his head had rested, as a pillar (Genesis xxviii. 18); it is also recorded

that after the discomfiture of the Philistines, the prophet Samuel "took a stone, and set it between Mizpeh and Shen, and called the name of it Eben-ezer" (Samuel, vii. 19): indeed, frequent mention is made of such stones of memorial throughout the Old Testament. In many places, a superstitious regard is still paid to them. In Iona there are several of these unhewn pillars, called "black stones," on account of the awful punishment supposed to follow the violation of an oath sworn upon them. These maen-hir were also used to mark the resting-place of the dead, though the Hebrews, like other eastern people, preferred a cave or excavation as a place of sepulture; when no rock was at hand, they made use of these stones of memorial: thus we read, that when "Rachel died, and was buried in the way to Ephrath," "Jacob set a pillar upon her grave: that is the pillar of Rachel's grave unto this day" (Genesis, xxxv. 19, 20).

It was a custom amongst the ancient Greeks to set an upright stone on the summit of a tumulus: it is, no doubt, in these stones of memorial that the head-stones in our modern cemeteries have originated. Upright stones were also used as a "kebla," or point of observation, to which the attention of the worshippers should be directed. Broad flat stones were used as stones of inauguration: the stone under the coronation chair at Westminster Abbey is of this description. It is supposed to be the same that stood upon the Hill of Tara, on which the kings of Ireland were inaugurated in ancient times. There was an old prophecy to the effect, that the same race should reign wherever this stone should be; consequently, when an Irish colony settled in North Britain, this stone was sent with them to confirm their dominion: it remained at Scone, where it formed the coronation chair of the Scottish kings, until the time of Edward I., who had it removed to Westminster Abbey, in defiance of the prophecy. Toland observes of this stone, that it is "the ancientest respected monument in the world, for although some others may be more ancient as to duration, yet thus superstitiously regarded they are not."

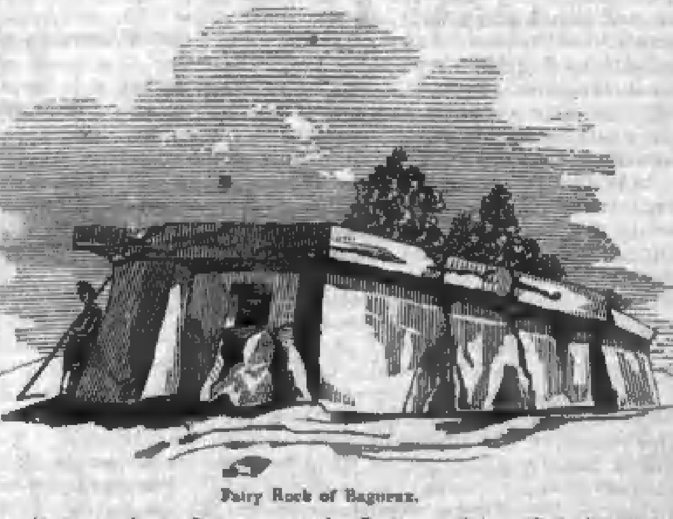
The *Cromlech* (from *crum*, "bowed or inclined," and *llech*, "a broad flat stone") consists of a flat stone resting upon two or three uprights, with the upper stone generally inclining from the horizontal. The largest cromlech in England is that in the parish of Constantine, Cornwall: it is 36 feet in length, 19 ft. 8 in. in width, and 16 ft. 4 in. in thickness, its weight being about 750 tons. One of great size is also found at Plas Newydd, in the island of Anglesea. These cromlechs are generally supposed to have been altars, and are met with in every known country. It was a custom of the patriarchs to offer up their sacrifices at an open altar; we learn from the Talmud also, that before the erection of the tabernacle, religious rites were performed at open altars and on high places. The first mention in the sacred writings of a place set apart for worship was at Beersheba, where Isaac built an altar in the grove which his father Abraham had planted, and where he "called upon the name of the Lord" (Genesis, xxvi. 25.) It had been the custom from time immemorial to dedicate a grove as a place of worship; the rude hut or tent were too closely associated with the avocations of daily life, to become impressive as temples: the sultry climate of the east gave the inhabitants a great love and veneration for trees, which they naturally considered as amongst the most beautiful of God's creations, and they gladly retired to the umbrageous recesses of the grove to meditate and pray. On account of the idolatrous rites practised, the Jews were afterwards forbidden by their law to plant groves for worship; but in other countries, after the erection of temples, they were surrounded by a sacred inclosure, generally planted with trees, after the type of the altar in the grove.

We find the mention of unhewn stone altars in Exodus xx. 25: "And if thou wilt make me an altar of stone, thou shalt not build it of hewn stone: for if thou lift up thy tool upon it, thou hast polluted it." And again, in Deuteronomy xxvii. 5, 6: "And there shalt thou build an altar unto the Lord thy God, an altar of stones: thou shalt not lift up any iron tool upon them...Thou shalt build the altar of the Lord thy God of whole stones." Among the Romans, these unhewn altars or cromlechs went by the name of Fanum Mercurii. Strabo alludes to them in describing Egypt: he says that he saw on every hand altars of unhewn stones, composed of two uprights with a horizontal block across, and calls them temples dedicated to Mercury. Arrian informs us that similar altars existed in Asia Minor; and they are frequent in Italy:

> "Far off, concealed by pointed reeds, I'll stand,
> Or else beneath some altar, near at hand."
>
> —Eclog. Third.

It is to be feared that under the Druids, these cromlechs were too often stained with human blood: in many of them basins are scooped out of the upper surface; and though these, as on the fire-altars of Persia, might be for a different purpose, the duct or channel leading from the basin to the edge of the stone, would seem to have been intended to carry off the blood of the victim. According to Mallet, 'Northern Antiquities,' in Sweden and Norway, they are still called "*blod*"—that is, blood-stones. Tacitus, in his account of the Isle of Mona (Anglesea), says that the Romans there cut down forests, in which the natives had been accustomed to practise the most cruel superstitions, making the altars smoke with the blood of their captives, and consulting the Divinity by inspection of the entrails of the victims; and Holinshed, speaking of places "compassed about with great stones round like a ring," adds, "But towards the south was one mightie stone, farre greater than all the rest, pitched up in manner of an altar, whereon their priests might offer sacrifices in honour of their gods."

The *Dolmen* (from the Celtic *taol* or *daol*, "a table," and *maen*, "a stone,") are nearly the same as cromlechs on a larger scale, excepting that the horizontal stone at the top is not inclined, but level, like (as its name denotes) a stone table: these are supposed to have served both as altars of sacrifice and dwelling places for the priests. The Fairy grottoes, or Fairy rocks as they are sometimes called, are dolmens of great size; some of these have the appearance of a corridor, ending in an irregularly-formed chamber; others approach the circular form, and a few are divided into two or three apartments. One of the most perfect of these constructions stands a



Fairy Rock of Bagneux.

short distance from Saumur on the Loire, and is called the Fairy Rock of Bagneux; the stones supporting the table are 7 feet in height; the outside width of the dolmen is 14 ft. 4 in, and the sides each composed of four stones, 57 ft. 6 in, in length. A single upright stone in the centre gives additional support to the roof or table. In this dolmen we see the original type of buildings in stone: the sides slope inwards to the roof, and the huge block of which this is formed gives the massive entablature; the builders would perceive that it was desirable to shelter the walls from the dripping of rain, and would place the horizontal block with its broadest side uppermost, so as to form an overhanging ledge; when they began to hew their stones, they would chisel this out smooth, leaving a ridge below to conceal the joining of the horizontal and vertical stones,—thus producing the most ancient form of moulding, the bead and cavetto; the first rude idea of an Egyptian temple would then be complete. M. de Fremenville mentions the remains of a dolmen on the shores of the bay of Morbihan, on some of the stones of which hieroglyphics were carved; but these have unfortunately been destroyed.

The *Kist-vaen*, or stone chest, is a sort of rectangular cell, formed by a flat stone resting upon three uprights composing the three sides, the fourth side being left open. They are supposed to have been sepulchres, and also places of initiation. One of the best specimens is in Kent, and is now called Kit's Coty House: Camden supposes this monument to have been erected over the tomb of Catigern, an ancient British hero. In Wales there is a circle composed of several kist-vaens, with a cromlech in the centre; under the kist-vaens human bones have been found.

The *Circles of stones* were sacred inclosures and places of public meeting, either for civil or religious purposes. These are also found in various countries: a circle of stones, with an upright stone in the centre, still exists near Darab, in Persia; and it is

said that three circles have been found in America. Cæsar informs us that the Druids in Gaul sat in a consecrated place at certain times of the year, when people flocked together from all parts of the country. Here judgment was passed upon criminals, rights of inheritance and boundaries of land established, and disputes, public and private, settled by a decree to which all submitted. In Iceland these circles are called "*domr ringr*," that is, "doom rings," or circles of judgment. In an ancient Welsh poem we find the following allusion to these consecrated inclosures: "Bards were constituted the judges of excellence, and bards will praise thee, even Druids of the circle;" and in another passage the poet says, "It is my right to be master of song, being in a direct line of the true tribe, a bard of the inclosure."

Of these sacred circles, Stonehenge is the largest and most perfect, and has from time immemorial been considered one of the wonders of the world. The name is derived from the Saxon *stan*, "stone," and *henge*, "hanging," or as some translate it, the "stone gibbet," in allusion, I suppose, to the huge trilithons forming so conspicuous a part of the ruins. This temple (for so it may be called) consisted originally of two circles and two ovals, which latter formed the sanctuary; the outer circle was about 300 feet in circumference, and was composed of lofty upright stones, with others placed across to form a kind of architrave. This circle consisted formerly of 30 stones, of which 17 remain standing. Within this is another circle, composed of small unhewn stones. The largest oval was formed by five pair of trilithons; the highest one now standing is 22 ft. 6 in., but one that has fallen and broken measures 26 ft. 8 in. The horizontal stones are attached to the uprights by joggles. According to Dr. Stukeley, the inner oval was composed of 19 stones. The altar stone is 16 feet in length, but is almost covered by the fall of one of the great trilithons. The whole structure was surrounded by a "vallum," 369 yards in circumference; and here we find an instance of the distinction made in ancient earthwork between the military and civil or religious structures—in the former the ditch is outside the rampart, and in the latter invariably within. There is many a tradition connected with Stonehenge, but no positive history. Hecatæus of Abdera, an officer in the army of Alexander the Great, in his history of the Hyperborean nations, speaks of a "temple of the sun," in evident allusion to Stonehenge. It is also mentioned by the Welsh Bards: in one of their songs, the "stone cell of the sacred fire" is celebrated, and is considered as the great sanctuary of the dominion. It is curious to meet with these constant allusions to sun and fire worship—another proof of the prevalence of some primitive and universal faith. In Ireland, there is a rock with a basin scooped out of its upper surface, that goes by the name of *Carig-Croith*, the "rock of the sun." Sacred stones, such as those of Stonehenge, were distinguished by the ancients by the name of "amber," signifying anything solar or divine: hence, Stonehenge was sometimes called "Maen-amber," and gave the name of Ambresbury, now Amesbury, to the nearest town. Giraldus Cambrensis, who lived in the middle of the twelfth century, calls these stones "the Giants' Dance," and says they were brought by giants from Africa, and set up in Kildare; they were afterwards removed from Ireland to Salisbury Plain by the power of the enchanter Merlin. Jeffrey of Monmouth, who wrote in the same century, also relates the tradition, as follows:—"Aurelius, wishing to commemorate those who had fallen in battle [speaking of a battle between the British and Saxons], and who were buried in the convent of Ambresbury, thought fit to send for Merlin the prophet, a man of the brightest genius, either in predicting future events or in mechanical contrivances, to consult him on the proper monument to be erected to the memory of the slain. On being interrogated, the prophet replied, 'If you are desirous to honour the burying-place of these men with an everlasting monument, send for the Giants' Dance, which is in Killaræus [Kildare], a mountain in Ireland; for there is a structure of stones there, which none of this age could raise without a profound knowledge of the mechanical arts. They are stones of a vast magnitude and wonderful quality; and if they can be placed here, as they are there, quite round this spot of ground, they will stand for ever.' At these words, Aurelius burst into laughter, and said, 'How is it possible to remove such vast stones from so distant a country? as if Britain was not furnished with stones fit for the work!' Merlin having replied that they were mystical stones, and of a medicinal virtue, the Britons resolved to send for the stones, and to make war upon the people of Ireland if they should offer to detain them. Uther Pendragon, attended by fifteen thousand men, was made choice of as the leader, and the direction of the whole affair was to be managed by Merlin. On their landing in Ireland, the removal of the stones was violently opposed by one Gillomanius, a youth of wonderful valour, who, at the head of a vast army, cried, 'To arms, soldiers! and defend your country: while I have life, they shall not take from us the least stone of the Giants' Dance!' A battle ensued, and victory having decided in favour of the Britons, they proceeded to the mountain of Killaræus, and arrived at the structure of stones, the sight of which filled them with both joy and and admiration. And while they were all standing round them, Merlin came up to them, and said, 'Now try your forces, young men, and see whether strength or art can do more towards the taking down these stones.' At this word, they all set to their engines with one accord, and attempted the removing of the Giants' Dance. Some prepared cables, others small ropes, others ladders for the work,—but all to no purpose. Merlin laughed at their vain efforts, and then began his own contrivances. At last, when he had placed in order the engines that were necessary, he took down the stones with an incredible facility, and withal gave directions for carrying them to the ships, and placing them therein. This done, they with joy set sail again to return to Britain, where they arrived with a fair gale, and repaired to the burial-place with the stones. When Aurelius had notice of it, he sent out messengers to all the parts of Britain, to summon the clergy and the people together to the mount of Ambrius [Ambresbury], in order to celebrate with joy and honour the erecting of the monument. A great solemnity was held for three successive days; after which, Aurelius ordered Merlin to set up the stones brought over from Ireland, about the sepulchre, which he accordingly did, and placed them in the same manner as they had been in the mountain of Killaræus; and thereby gave a manifest proof of the prevalence of art above strength."

Aurelius Ambrosius succeeded Vortigern in the year 465 A.D. Aylett Sammes, who wrote in 1676, refers Stonehenge to a Phœnician origin, thus explaining the legend of the African Giants; and it is singular that the stones of which Stonehenge is principally composed are called "sarsen-stones," *sarsen* being the Phœnician word for "rock:" it is a common saying amongst the Wiltshire peasantry, "As hard as a sarsen." Numerous stones of the same formation are scattered over this part of the county, and on Marlborough downs are strewed about so thickly, as to gain for the place the appellation of "Grey wethers," the stones in the dusk of the evening appearing like an immense flock of sheep. According to Dr. Stukeley, a tablet of tin was found at Stonehenge in the reign of Henry VIII., inscribed with strange characters that none of the antiquarians of that age could decipher. James I., in 1620, employed the celebrated architect, Inigo Jones, to collect information concerning Stonehenge; who came to the extraordinary conclusion that it was of Roman origin,—but this singular opinion does not need refutation. From all these authorities, it will be seen how very little is known respecting this wonderful structure: in fact, all the information we possess respecting it amounts to this—that such a pile *was* erected near Amesbury, and that it was considered a marvellous work by our most ancient authors.

Another extraordinary temple stood 19 miles distant, at Abury, of the form of a serpent transmitted through a circle—according to Dr. Stukeley, a hieroglyphic of the highest note and antiquity. The serpent was greatly venerated amongst the ancients, being considered a symbol of renovation or immortality, on account of its annually shedding its skin. When temples were built in this form, they were called Dracontia. Serpents were constantly introduced on antique altars and coins. The temple of Abury was constructed of huge unhewn stones; the great circle was inclosed within a vallum of 1400 feet in diameter. The two serpentine avenues of upright stones, called the Kennet and Beckhampton avenues, forming the neck and tail of the snake, were each a mile in length; the Kennet avenue ended in a small circle of stones on Overton-hill, formerly called Hackpen, from the Saxon words for snake-head. The whole construction is supposed originally to have consisted of 650 stones. Mr. Aubrey, who lived in the reign of Charles II. was enabled to make out the whole plan of the temple from existing remains; he has left a description of it in manuscript, which he refers to the following source: dated 1663 A.D. "King Charles II. discoursing one morning with my lord Brounker and Dr. Charlton concerning Stonehenge, they told his Majestie what they had heard me say concerning Aubrey (or Abury), for that it did as much excel Stonehenge as a cathedral does a parish church. His Majestie admired that none of our chorographers had taken notice of it, and commanded Dr. Charlton to bring me to him the next morning. I brought with me a draught of it, done by memorie only, but well enough resembling it, with which his Majestie was pleased, gave me his hand to kisse, and commanded

me to waite on him at Marleborough, when he went to Bath with his queen (which was about a fortnight after), which I did; and the next day, when the court were on their journey, his Majestie left the queen, and diverted to Aubrey; with the view whereof, he and his royal highnesse the Duke of Yorke, were very well pleased. His Majestie then commanded me to write a description of it, and present it to him; and the Duke of Yorke commanded me to give an account of the old camps and barrows in the plains."—Since the time of Mr. Aubrey, the destruction of this fine memorial of past ages has been complete; the stones of which it was composed having been broken up to serve as building material for the modern village of Abury, situated within the ancient vallum. The snake-head remained till within a few years, when the farmer on whose land it stood had the stones removed and the ground ploughed over.—Numerous small circles of stones are met with in England and elsewhere, but do not require any particular description.

I shall leave the mention of the camps and cities of our Celtic and British ancestors to a future period, and shall invite the student, in the next Lecture, to return with me eastward, to consider the Pelasgic remains of Greece and Italy, the architecture of the Jews, and the ancient remains of Asia Minor.

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ENGINEERING EMPLOYMENT.

In our former article (p. 26) we made some remarks on engineering employment, and the opening there is in agricultural operations. Since then, Mr. Cubitt, on taking the chair of the Institution of Civil Engineers, and making his presidential speech, has taken up the same subject (*vide* p. 41). We have latterly been under a dearth of work, from the slackening of railway undertakings; but it is to be hoped, with the awakening of trade throughout the world, we have a better time before us. Nevertheless, there is one great duty on every member of the profession, and that is, to uphold it. What the members of the Institution bind themselves to do, every member of the profession should likewise undertake. Let each do something to increase the field of knowledge, and let each do something to increase the field of employment, for by keeping up the common interests, so is the interest of each best kept up.

The lawyer, being a trained man of business, has laid hold of a wide field of employment. Although litigation is very profitable, yet with the higher solicitors it forms but a small part of their emoluments; they are the chief counsellors of the landowner and the trader, in all money matters. They are agents for boroughs, stewards for manors, advisers as to lending and borrowing money, as to buying estates and selling them, marrying, settling, and willing away. The counsellor who has a bosom knowledge of a man's business, has a share in his well-being, and becomes his friend as well as his adviser; knit up in the same undertakings, and having the choice of every enterprise as well as the immediate reward for professional exertions.

Men of property want, however, other advisers. The man of law has no time for geology or chemistry, bricks and mortar, or earthwork; these are what the engineer can undertake, if he will but put himself in the way of doing so. The beginning of the connection, however, is everything, and the reward to be looked for is not immediate but permanent. It will often happen in our professional pursuits, as with the lawyer, that what costs us most labour is of least worth to our client; and whatever we may set up as to the labourer being worthy of his hire, modern political economy is much fonder of another saw—that a man shall not be asked to give more for anything than it is worth to him. In one year the lawyer may do much work and get small pay; in the next he may do little, and yet have the means of making the highest charges. Nothing can be so valuable to a client as a proceeding by which a costly litigation may be saved; and yet the attorney may not be able, by putting in all the conventional "six-and-eightpences" he can, to screw up his bill to more than a pound. So with the engineer, he may make half-a-dozen plans, and only one be adopted, though unquestionably the time for all six is spent in the work. On the other hand, the landowner cannot afford to pay for five plans which are not worth a farthing to him.

The merchant, if he knew he could have the services of an engineer on moderate terms, would often refer to him—but the landowner has still greater need of such help; and it is to be remembered there are small landowners as well as great ones, as there are small traders as well as great ones. There is very little difference in the amount of talent and exertion required between a little plan and a great one, but there is very much difference between the means of remuneration; and this is what we want the engineers, and particularly the young ones, to bear in mind. Professional etiquette is a very fine thing; but what is called professional etiquette in most professions is, like trades' unions among mechanics, only a means of increasing the monopoly for the big men, and rewarding the lazy and stupid from the earnings of the hard-working.

Here we will stop a while for a few words on "professional etiquette," which may in most cases be put in the common tongue as "professional remuneration." Engineering is now acquiring a professional organisation, and the time is near when the questions of a professional test and professional etiquette will spring up, and be worked to the injury of the profession, unless the members take heed. Engineering is now an open profession, taking talent from every quarter—from the coal-heap, the mine-shaft, the quarry, and the work-bench, no less than from the desk and the college; and it is to be hoped no coxcombry will ever be allowed to alter this state of affairs, but that the field shall be free to all, and, above all, to the working man; and be it remembered, that after all that is said, this is the only field of ambition open to the ingenious mechanic. The architects are meeting this matter of professional test, and some of them want to have certificates; when, if they could see their true interest, they would throw open the field for admission, and invite more talent—whereas they actually propose to shut out some of what they have, and have a ridiculous regulation to cut off the surveyors from their body. As it is, the architects are being driven out by the engineers, who have no restrictions; and the struggle will be still less doubtful when it is the few articled pupils against the talent of all England enrolled among the engineers. Hitherto the architects have had the government patronage, certain official appointments, knighthoods, a share in the Royal Academy, and other good things. Notwithstanding this, the engineers have beaten the architects in public estimation; and notwithstanding the engineers have had the hostility of the government, who have defrauded them of the public appointments due to them, and put military officers and corporals in their places.

Professional etiquette or professional remuneration means that there shall be a certain scale—that a young man shall not charge lower than an older one, and consequently, that the older one, who is known, may be employed in preference to the younger one, though the latter may have the talents of a Watt or a Stephenson. As this doctrine is set up on a wrong economical groundwork, it always works ill. It looks to the interest of the professional man, and not to the means of his employer; and the class most injured is therefore that of the professional men. Take the case of a solicitor who has to deal with a uniform scale: many kinds of business he cannot undertake, and for many he can get no proper remuneration, because the scale has no reference to the benefit done to the employer, but only to the work done by the lawyer. Take the case of the medical men, who, by the results of professional etiquette, have pauperised the working classes of this country, keep up dispensaries for the benefit of "pure" physicians and surgeons, and the demoralisation of the out-patients, and who lose, on the lowest estimate, a million a-year, which they might obtain by small fees from the labouring classes. In France, a young man can begin with a shilling fee, and he goes on increasing his scale as his practice enlarges, so that we believe at Paris the highest medical remuneration is higher than in London. So among artists, they may begin with a shilling or half-a-crown, until their lowest charge is two hundred guineas.

There is many a man with three or four hundred acres, who would like to know what he can do with them for the best; for unless he keeps a sharp look out, his rents are likely to be much lessened—not by free trade, but by protection and agricultural ruin; a war-cry which the farmers having been once taught by the landlords themselves, are not likely to give up without getting something by it. The farmers have already screwed down their workmen, and they are trying their hands with the landlords to get something off their rents. A landowner with a small holding, cannot afford to send for a great engineer, or an engineer who wants a great fee; but he would be very glad to have sound advice as to what can be done. If he has minerals underground, that

ought to be known,—if clay or lime aboveground, he will think about tile or lime kilns. A fair analysis of the soils is to be made, to know whether anything is wanting in them, and whence it is most readily to be got. The streams of water must be looked after, and it must be settled what is to be drained off, and what can be kept for catchwater meadows, or to feed the crops. It may be worth while thinking whether wells should not be sunk, to water the cattle where the land drainage is not wholesome. The roads settle the number of draught horses to be kept; and a few yards of quagmire filled up will perhaps get rid of half the horses. The hedges, trees, buildings, machinery, dung-pits, must be looked to, mapped out, and reckoning gone into as to what is to be done with them.

A great landowner can send for Mr. Parkes, or Mr. Smith of Deanston to plan works, Mr. Bailey Denton to lay down a survey, Prof. Phillips to examine his minerals, and Prof. Johnston to analyse the soils; but the small landowner wants this done by one man, at a small rate. The farmer, or the schoolmaster who is a land-surveyor, can plot out the ground—but there he ends. There are many farmers and land-valuers who can give very good advice as to draining or laying out the farm buildings; but still they cannot do the whole work. A young man who has been fairly brought up can do all that is wanted. He must be a surveyor, engineer, geologist, and chemist: know how to plan and estimate buildings; but, above all, he must be a good accountant—one of the first qualifications of a man of business.

The engineer is becoming the counsellor of his employers in many great undertakings, and his success will be much dependent on his knowledge of business. Now, so far as we know, in the engineering schools, book-keeping is not taught, and neither is political economy. We ought perhaps to go further, and say that logic and the training of the mental powers are not taught. The technical knowledge of accounts is needful to every engineer who would be more than a mechanic, for our's is a truly practical profession; and without knowing what the outlay will be, and what the income, a man who lays down a plan is a mere bubble-blower, and may as well lay down a bridge from Dover to Calais, for which the gold diggings of California would never pay,—or set up a patent cabbage-cutting machine, such as that which saved one cabbage in a hundred, but trampled down four. For want of a knowledge of higher political science, engineers are unable to grapple rightly with all the bearings of the plans which come before them. In common arithmetic, two and two make four; but in political arithmetic, they may make five, four, three, or even two.

An engineer who is called in to look over land is not called in to spend money, but to save it. He must look to the means of his employer. If the latter is short of money, then only those works must be set about which are altogether needful: if, however, he has money to spare, then it is worth while to lay it out in every way which will bring a good return. Everything must be well reckoned up. The whole mileage of carts and horses throughout the year, must be worked out,—whether this can be shortened, whether lighter carts can be run, or other kinds of ploughs be brought to bear. When buildings are to be set up, it does not follow they are to be built off-hand of brick or stone; but it must be worked in every kind of way, to make the most of the stone, brick, timber, and lime at hand. To liken great things with small, if railways had been so worked, they would now yield a much better income.

A farm is a factory for bread and meat, and is to be set up in the same way as a cotton-mill. The engineer is the man to undertake the task, for neither landowner nor farmer can do it without him. One set pattern does for a windmill or a baker's oven, but no two farms are alike. One is high, another low; one wet, another dry; and so forth; and there must be a plan for each.

This constitutes the protection of the engineer, for if a plan could be stereotyped and lent about from landowner to landowner, as a crotchet pattern by their wives, small would be the extent of engineering employment. It is on the degree of skill displayed in each design, in its peculiar and specific application to the circumstances, that the engineer must depend for his reputation. If he contents himself with copying from books, or with mixing up stock plans, either in this or any other branches of engineering employment, he is only undermining himself, for his employers can do the same thing, or others can start against him.

We repeat, that protection is not to be sought in a code of conventional etiquette, but by the upright discharge of professional duties towards employers, looking not to selfish emolument, but to mutual advantage where a mutual service is rendered, and where a mutual interest is at stake. Those who hire themselves out for the day will be treated as hirelings: those who do unto others as they would others should do unto them, will be treated as friends, and rewarded as such.

ON THE LIFE AND GENIUS OF VIGNOLA.

On the Life, the Genius, and the Works of Giacomo Barozzi Da Vignola. By SAMUEL ANGELL, Esq., Architect.—(Paper read at the Royal Institute of British Architects, Feb. 4th.)

Of the great Italian architects of the sixteenth century, I doubt whether there is one to whose works and instruction we are more indebted than to him, who forms the subject of the present paper, Giacomo Barozzi da Vignola. We have all probably our different favourites among these great masters—one preferring the grandeur and solidity of the San Galli; another, the refined elegance of Peruzzi; a third, the harmony and simplicity of Palladio; but for a happy combination of exquisite grace, with originality and purity of design, I consider Vignola as deserving the palm.

In France the merits of Vignola have always been justly appreciated. The architect is there taught from the commencement of his studies to revere him as his law-giver, and his name has given the title to several of the French elementary works. They have their 'Vignoles des Architects,' 'Le Vignole des Ouvriers,' and 'Le Vignole des Proprietaires.' They have produced 'Le Vignole in fol.' and 'Le Vignole de poche;' in fact, for pure Italian architecture this great master is looked up to as their standard, and I believe I am correct in attributing the great excellence of modern French architects to the fortunate selection they have made of Vignola as their chief guide and instructor.

Of our own countrymen, Sir William Chambers has, perhaps, been the most forward in doing justice to the merits of Barozzi. In Sir William's admirable treatise he constantly refers to the writings and executed works of his great Italian prototype, and in his Five Orders he has drawn more largely from Vignola than from either Scamozzi, Serlio, or Palladio.

Our Honorary Foreign Secretary has also done justice to the genius of Vignola in the following passage, from his instructive work on Doorways:—"We are not sufficiently acquainted in this country with the powers of Vignola's mind, which is more to be regretted, as all his works evince a profound knowledge of the resources of his art, and a taste of the most cultivated and refined nature. Grace is the predominating feature in all his buildings, not one of which but is sufficient to establish the reputation of any man."

Before I proceed to discuss the merits of Vignola as an architect, I will first slightly glance at the history of his life, and describe some of his principal works. Of the former I have little to add to what is contained in his memoir by Vincenzio Danti, as well as in Milizia's 'Memoire degli Architetti;' and also in the accounts prefixed to the editions of his works, well known, no doubt, to those present. And although I can offer no such amusing scenes, nor stirring events as are to be found in the life of a Benvenuto Cellini, still the career of Vignola was not without its shadows: occasionally basking in the sunshine of royal favour and pontifical patronage, there were times when he despaired of success, and when he found it necessary to change the intent and nature of his studies.

Vignola was born on the 1st of October, 1507; his father, Clemente Barozzi, was of a noble family, and a native of Milan; his mother was a German lady. The civil wars of that period obliged Clemente to leave Milan, and he took refuge in the small town of Vignola, in the Modenese states, and Giacomo being born there, was, according to the custom of those days, surnamed after the place of his birth.

Clemente Barozzi died during the infancy of Giacomo, who, as he grew up, evinced some talent and inclination for drawing, and was therefore advised to proceed to Bologna to study the art of Painting and Design. He does not, however, appear to have made the progress in his pursuits that he desired, he therefore took the resolution of changing them for Perspective and Architecture; and in these, his more congenial studies, he soon arrived at that proficiency which his natural genius and constant application enabled him to attain. Francesco Guicciardini, at that time governor of Bologna, took him under his patronage, but the youthful Vignola, perceiving that a thorough knowledge of architecture not merely consisted in making designs, or studying the works of Vitruvius, determined to proceed to Rome, and

there to measure and study those glorious remains of ancient magnificence for which he had so profound a veneration.

He at first obtained employment by making drawings for Melighini of Ferrara, the same unfortunate wight, who, it is said, served his holiness in capacity of groom, and who, upon the occasion of the competition for the *Cornicione* of the Farnese Palace, was called by Antonio Sangallo "that mountebank of an architect." The necessity of procuring the means of subsistence obliged Vignola occasionally to resort to painting small pictures for sale, but this precarious mode of life was so distasteful to him, that upon the formation of an Academy of Architecture in Rome, by Monsignore Marcello Cervini (afterwards elevated to the papal chair), he gave up painting and devoted himself entirely to the study of architecture, drawing and measuring nearly all the then existing remains for the use of the academy, and to the entire satisfaction of its members.

About the year 1537, Vignola left Rome in company with Primaticcio, the painter, who took him with him to France, and presented him to Francis the First, to whose service he became attached as professor of design. He made several drawings of ancient monuments for that great monarch, and various designs, the execution of which was prevented by the wars and troubles of that period. Some of his designs in perspective are said, however, to have been executed upon the walls of the palace at Fontainbleau. Vignola appears also to have assisted in casting in metal several statues from the antique for that palace, but Francis the First, having other occupations and demands upon his time and treasure, was obliged to withdraw his patronage from the fine arts, and our architect therefore returned to Bologna at the invitation of Count Filippo Pepoli, president of S. Petronio, and he was engaged up to the year 1550, in making designs for that establishment.

Competition designs in the sixteenth century do not appear to have been managed with more satisfaction to the parties engaged, than in the nineteenth: and Vignola is said to have been troubled with many dissatisfied rivals, when Giulio Romano and Christoforo Lombardi being called in to advise (much in the same way as in our own times) upon the designs sent in for the restoration of S. Petronio, Vignola's was adjudged by those two great artists to be the most meritorious. This account, however, does not quite agree with Giorgio Vassari's statement, in his life of Giulio Romano, from which it would appear that Giulio Romano himself made a design for the façade, which was much admired by the Bolognese. Palladio made four designs, and Baldassari Peruzzi and Alessi were among the competitors. The affair appears to have created a great sensation in the architectural circles throughout Italy at that period. These designs are still preserved in the Reverenda Fabrica, at Bologna (adjoining S. Petronio); they were seen by Mr. Falkener and Mr. Newman last year. Vignola's design is of a Gothic character, in accordance with the other parts of the building; it does not appear so meritorious as Giulio Romano and Lombardi adjudged it to have been.

We gather from Milizia, that it was the custom at that time to consult the chief architects of the day upon any questionable point of design or practice, for in a dispute between Bassi and Tibaldi upon some matter connected with the works in progress at Milan Cathedral, Bassi applied for the advice of Palladio, Vignola, Vassari, and Bertani; and Milizia remarks that the answer of Vignola as respected the Baptistery was well worthy of being recorded. Tibaldi, in order to support his ill-proportioned intercolumniations, proposed to introduce iron chains, Vignola remarked, "*Che le fabbriche non si hanno da sostenere colle stringhe*,"—"a golden sentence," as is well observed by the ingenious and learned author of the 'Notitia.'

Vignola appears about this period to have been employed upon a palace at Minerbio, for the Conte Alemano Isolani, and upon a house for Achille Bocchi, in Bologna: upon the Façade dei Banchi in that city; and upon the Canal of Naviglio, a work of engineering, which architects then undertook as a legitimate part of their profession.

My friends, Mr. Edward Falkener, and Mr. Newman (both of whom have lately returned from Italy with rich stores of architectural study) were induced, from finding the palace at Minerbio described as a great work of Vignola's, to make a detour of some twenty miles to see it, and we may judge of their disappointment upon finding the only work of Vignola's now existing at Minerbio to consist of a Columbajo, of an octagon form, about 29 feet in diameter, and 70 feet in height. No traces of the palace could be found; but if that building was in proportion in extent of accommodation to the Columbajo, which would contain 13,000 pigeons, it must have been a building of no little magnitude.

Upon a second visit to Rome, Vignola was introduced by Giorgio Vassari to the Pope Julius III, who, when legate at Bologna, was acquainted with Barozzi. His holiness appointed him as architect, giving him the direction of conducting the Acqua di Trevi, and commanding him to make designs for his celebrated residence, the Villa Papa Giulio; he was also engaged upon the small neighbouring Church of S. Andrea a Ponte Molle.

The Cardinal Alessandro Farnese was a most influential patron of Vignola's. He employed him upon that portion of the Farnese Palace known as the Caracci Gallery, and his hand may be traced in other parts of this celebrated building. He was engaged at the Cancellaria; and he also designed for the Cardinal the exquisite gateway to the Orti Farnesiani in the Campo Vaccino. The greatest work, however, upon which this powerful prelate employed him, was that superb specimen of architecture, the palace of Caprarola.

At the decease of Michael Angelo, in 1564, Vignola was appointed architect to St. Peter's, and to his refined taste we are indebted for the two beautiful lateral cupolas of that building. The Church of the Gesù in Rome was also a commission from the Cardinal Alessandro Farnese; the foundations were laid in 1568, but the works were only carried up to the height of the cornice by Vignola. The building was completed under the direction of Giacomo della Porta.

The great Ducal Palace at Piacenza was designed by Vignola, but completed by his son Giacinto. A chapel in the church of San Francesco in Perugia, the Capella Ricci in Santa Caterina de' Funari at Rome, the church of Santa Anna dei Palafrenieri, the Oratorio di San Marcello, and the tomb of the Cardinal Ranuccio Farnese in San Giovanni Laterano, were among the works of Vignola about this period; and he was also employed upon several public and private edifices in various parts of Italy, among which were the Chiesa della Terra di Manzano, that of S. Oreste (Mount Soracte), and Santa Maria degli Angeli at Assisi.

The foundations of the Palace of the Escurial were laid in 1563, when the Baron Martirano being at the court of Philip the Second, and being much esteemed by that monarch as of acknowledged taste in the arts, he was consulted in respect of this important building, and commissioned to return to Italy to advise with the most celebrated architects of the day,—Galeazzo Alessi at Genoa, Pelegrini Tibaldi at Milan, Palladio at Venice, and the Academy of Design at Florence. The grand duke Cosmo di Medici also ordered a design to be made by Vicenzio Danti. No less than twenty-two designs from different architects were collected on this occasion; but it is stated that none were so well received by the King of Spain and Martirano as that by Vignola, who, having had all the designs sent to him for his inspection and judgment, selected the best parts of each, and thus dressed up a description of *olla podrida* design for his most Catholic Majesty. This at first sight does not appear to have been a very creditable proceeding on the part of our architect, but at this distance of time it would hardly be just to venture a censure without having all the circumstances of the case before us; and as the character of Vignola for honour and integrity has never been impeached, it is only fair to presume that he did nothing unworthy of it in this transaction. Philip invited Vignola to proceed to Spain to superintend the execution of his design, but finding himself advancing in years, and being much occupied with his professional duties (more particularly with those pertaining to St. Peter's), he prudently declined the royal invitation, and determined upon continuing in his favourite Rome. The Escurial, according to Milizia, was afterwards erected by Giovanni Battista of Toledo, who commenced the work in 1563.

In the year 1573, Vignola was invited by Pope Gregory the Thirteenth to proceed to the city of Castello to examine into a disputed question of boundary between the Tuscan and Papal States; and although suffering greatly from indisposition at the time, he obeyed the pope's commands, and fulfilled his commission with care and great judgment. Upon recovering his health he immediately returned to Rome, and sought audience of the pope to render him an account of the successful performance of his commission; he remained an hour discoursing with his holiness upon the subject, and upon the state of the progress of several buildings from his designs, and received permission to proceed on the following day to Caprarola; but during the night he was attacked with fever, which terminated in his death after six days' continuance.

Vignola died on the 7th July, 1573, at the age of 66; he had requested to be buried in a private manner, but his son Giacinto was obliged to concede to the wish of his friends and admirers, and he was interred with great pomp in the Pantheon, all the members

of the Academy of St. Luke attending the ceremony, as a tribute of respect to his memory.

Ignazio Danti (to whom we are indebted for a Memoir of the Life of Barozzi) makes most honourable mention of his noble and generous disposition. His constant desire was not to be burdened with the cares of superfluity, or the miseries of want: his numerous charities prevented the former, and his talents and the extensive patronage he enjoyed rendered him exempt from the latter. His life was most virtuous! his love of truth proverbial! his manner cheerful and engaging! his accomplishments refined! He died poor, leaving no other inheritance to his son Hyacinth (observes Quatrèmere de Quincy) "than the example of his virtues and the reputation of his name!"

Milizia states that Giacomo della Porta studied under Vignola, and Bonanni styles him as *discipulus ejus;* he succeeded him as architect to St. Peter's, and also designed and executed the several churches and other important works in Rome.

I regret that I am unable to give the date when Vignola produced his celebrated Treatise upon Architecture. Daviler and Milizia both state that it was towards the latter end of his life, and this is in some measure confirmed by Vignola himself, who, in the following passage from his modest and unpretending preface says, "that having for many years practised as an architect in various parts, having studied the writings of several authors upon architecture, and having compared them together and with the works of antiquity then still remaining, he was desirous of establishing a rule upon which he might rely with security, and which might, upon the whole, or in part, please the judicious."

Of a treatise so well known to architects it will be unnecessary for me to offer any description, it being sufficient to observe that its merits have now been tested for more than three centuries; that of the parallels, which have been made of the orders with those of such powerful rivals as Serlio, Scamozzi and Palladio, I think the balance will be found in Vignola's favour, notwithstanding the opinion of so great a critic as Milizia, who places the great architects of the sixteenth century in the following gradation:—

"For knowledge and exquisite taste possessed by each in architecture, it appears that the first place would belong to Palladio! on his right hand would be Vignola, Buonarotti, Sansovino, and Vasari, and on the other Peruzzi, San Michele, Giulio Romano, and Serlio."

Vignola's Treatise upon Perspective was not published till after his death; his son Giacinto placed it in the hands of Ignazio Danti, a Dominican friar and mathematician of Bologna. Danti has well fulfilled his task of compilation, and has produced a work upon a subject, which was more carefully studied by the old Italian architects than by their successors. Both Vitruvius and Peruzzi, as well as Vignola, recommended its study as one of the means towards arriving at perfection in the art. The words of Vignola are "*La Scienza della prospettiva gli aveva aperto l'ingegno per l'arte di fabbricare,*" and I would here venture a remark to the students of the Institute upon the great importance of a sound knowledge of perspective for the proper study and practice of their profession. It would not be difficult to point out in several important buildings, instances of failure of architectural effect, arising from the designs having been merely studied geometrically.

Upon the principle so well laid down by Milizia, "That the best method of praising able artists is by making known their works," I will now proceed with a few remarks upon the executed works of Vignola at Rome, commencing with the little church of San Andrea a Ponte Molle, on the Via Flaminia.

The building was erected by Julius III., in commemoration of his escape on St. Andrew's day, 1527, from the German soldiery during the sack of Rome, and among the various inscriptions in the adjoining Villa Papa Giulio, Boissard gives the following as connected with this church. "In the neighbouring temple let thanks be given to God and St. Andrew, and let them (the visitors) pray for abundant health and eternal life to Julius III., Pontifex Maximus, to Baldwin his brother, and to their whole family.

This church is of a rectangular plan, of very moderate dimensions, and is chiefly remarkable for its resemblance in general exterior character to some of the small Roman temples. There is a great charm and beauty in the simplicity of the design, and the elegant details all bespeak the most careful study. Milizia, in his brusque way has some smart criticisms upon it, acknowledging at the same time that it was a work generally praised!

In the immediate vicinity of the Church of S. Andrea is situate the Villa Papa Giulio, commenced in 1550, by order of Julius III. I will not occupy the time of this meeting by a description of this building, with which, probably, nearly all present are familiar, either with the building itself or the charming illustrations of it by Percier and Fontaine. I cannot, however, resist the observation, that for the harmonious arrangement of the plan, for its style and character, for the refinement and delicacy of the enrichments, it is a model of suburban architecture. Ammanati in his fountains and ninfeo, and Zucchero in his beautiful paintings of the porticoes, have contributed much to its effect, but it is to the master-hand of Vignola, which guided and directed the whole, that we must award the palm!

My friend, Mr. James Morant Lockyer, who has with great credit given much attention to the study of numismatics, more particularly in reference to architectural representations upon medals, has kindly lent me a medal of Julius III., engraved both in Stern's and Letarouilly's works, upon which the Villa Papa Giulio is shown with two small cupolas surmounting the circular staircase and corresponding wing building. The effect in the medal is so successful, that I am induced to wish these lateral cupolas had been introduced in the building itself.

Near to the Villa Papa Giulio is the Vigna Giulia, and from their close vicinity and the resemblance in the names, the one building has sometimes been taken for the other in the works of Vasari and other authors. I am inclined to think the hand of Vignola may be traced on this latter building; it is an extremely picturesque composition and quite worthy of him. Letarouilly has treated this subject in his usual perfect manner, and he ascribes the design to Sansovino and Peruzzi. Giorgio Vasari states, that he himself was the first who designed it, adding rather indignantly, "that he was not one of those who made designs to please the capricious fancy of the pope, and which were afterwards obliged to be corrected by Michael Angelo and Vignola." From this passage it would almost appear, that Barozzi was really concerned in the design, but I have no doubt so careful an author as Letarouilly has good reasons for attributing the work to Sansovino and Peruzzi, and I am only doing justice to those two great architects in observing that the work in question is, at all events, worthy of Vignola. The Villa Lanti at Bagnaia, near to Viterbo, has also been ascribed to Vignola; it resembles his style, but it is not sufficiently refined and pure for that master.

At the Palazzo Farnese, Vignola executed that magnificent apartment so well known as the Caracci Gallery, with a portion of the Cortile, together with the decorations of several doors and windows, the most satisfactory details of which will be found in Letarouilly, who has also given as the works of Vignola, the lateral porticoes or loggie on the Capitol, the small Palazzo Spada in the Via di Capo di ferro, the Palazzo Nari, and a small palace at the extremity of the Piazza Navona. We have also the celebrated doorway of San Lorenzo in Damaso.

In reference to the entrance to the Farnese Gardens at Rome, I will again refer to the useful work on Doorways by Professor Donaldson, "It is useful, however, to consider whether this is an example to be entirely followed without reserve; certainly not;—but there are so few blemishes to remark, that it may appear almost unnecessary to notice them. It must be allowed, however, that the columns require being elevated above the level of the ground by a plinth. The rustications of the columns may be somewhat objected to as not sufuciently pure, but the harmony of the whole composition would have been destroyed had they been without; the attic is not sufficiently high, its proper proportions would have been to have equalled the entablature in height, this would have raised the plinth more above the cornice, and prevented its being intercepted by the projection of the latter. Some subsequent architect, with a taste as profane as it was daring, has introduced above this Capo d'Opera of Vignola, an attic, with caryatides, deteriorating materially its effect, and causing the deformity to be attributed to our great architect."

Now Milizia, who is generally not very sparing in his censure, is not quite so indignant as the writer whom I have just quoted, with respect to this "profane addition;" he merely says, "*Ma l'attico con quelle cariatidi è troppo grande,*" and upon referring to my own rough notes, I find that I was innocent enough to treat it as one design. Many, however, I dare say, will consider that the author of the work on Doorways has, in this instance, proved himself the best critic of the three, and that the addition must consequently be condemned as—

"A blot that will be still a blot, in spite
Of all that grave apologists may write."

At the death of Michael Angelo in 1564, Vignola, in conjunction with Pirro Ligorio, was elected as his successor as architect to St. Peter's, with the strictest injunctions from Pius IV. not in any way to alter the design made by Michael Angelo. Vignola's coadjutor,

however, thought proper to disobey these commands, in consequence of which he was dismissed, and Vignola remained as sole architect, and he so continued for the space of nine years, up to the time of his death. The lateral cupolas are his, and are well worthy of his master-hand. Milizia's praise of them is as concise as it is expressive: "*Sono del Vignola e sono belle!*" I am inclined to the opinion, that no other part of St. Peter's was designed by Vignola, but that he merely put in execution the designs of his great predecessor.

Through the patronage of Cardinale Alexandro Farnese, Vignola was appointed architect to design the important Church of the Jesuits. This great work was commenced in 1568, its plan is that of a Latin cross, the length is 216 feet, and the width 115 feet. The building was only carried up as far as the cornice by Vignola, it was completed by Giacomo della Porta, or according to Milizia, "*Il resto fu esagerato da Giacomo della Porta.*"

The garden front of the Palazzo dei Fiorentini, in Campo Marzo, is attributed to Vignola; it is a graceful composition, and has lately formed the subject of a work by Cavalieri Folchi, a copy of which has been presented to the Institute by the author during the present session.

The two lateral loggie of the Capitol are attributed to Vignola by Letarouilly; they are of extreme grace and simplicity, and their effect considerably enhanced by the grand flights of steps upon which they rest.

The Porta del Popolo is also said to be by Vignola; it is not, however, a very first-rate production, and I am not particularly anxious to claim it for my favourite. Some contend that the front only towards the Via Flaminia is by Vignola, and that towards the city by Michael Angelo.

I am not aware that there are any other important works at Rome by Barozzi requiring notice. Mr. Donaldson has suggested that parts of the Villa d'Estè at Tivoli, particularly the central loggia of the front next the gardens, are by his hand, and I am inclined to the same opinion.

Of Vignola's works at Bologna, my friend Mr. Newman, who was there last year, has kindly lent me a sketch of the Loggia dei Banchi, a wing of San Petronio. Mr. Newman is of opinion, that the facade was altered only, and not altogether designed, by Vignola; the lower pilasters without bases, and the proportion of the arches, induce a belief that the upper part alone must be attributed to our great master. Mr. Newman has also kindly furnished me with a powerful sketch of the palace built for Achille Bocchi. This is a noble production, and a glorious example of Vignola's genius for the grand and sublime, as well as the refined and elegant. Its massive grandeur reminds us of the Florentine palaces.

Of the great church, Santa Maria degli Angeli, at Assisi, I regret I cannot speak from personal observation, but the difficulty has been obviated through the untiring kindness of our friend Donaldson, he having furnished me with a plan of the building taken by himself in the year 1818. The dimensions are immense; the extreme length inside the walls being no less than 347 feet, and the width 180 feet, but notwithstanding this colossal size, I am far from considering it, in point of architecture, as the greatest work of Vignola; the plan presenting no new or striking features, and effect appearing to have been produced by magnitude alone. The first stone was laid 25th March, 1569, only four years before Vignola's death, and Alessi and Giulio Danti are said to have had the superintendence of the building after Vignola's designs.

In the year 1832 this church was considerably damaged by an earthquake, but it has been since repaired, and at the present time, is not merely celebrated as the work of Vignola, but as containing a superb fresco, "The Vision of St. Francis," a *capo d'opera* by one of our own century, Overbeck!

Of the great Ducal palace at Placenza, I have no illustration. My friend Mr. Falkener informs me that it is by no means one of Vignola's finest productions. I will proceed therefore to bring before the notice of the meeting Barozzi's greatest work, Caprarola!

Near to Viterbo, and distant about twenty-six miles from Rome, stands this *capo d'opera* of Vignola. The situation on the sides of Monte Cimino is wild and romantic, commanding magnificent views on all sides, and presenting the most striking points as the spectator approaches. The bold and rugged site no doubt influenced the architect in giving that fortress-like character to his building, alike suitable to the situation and to the stormy and turbulent times in which it was built.

Vasari says that the original design for the fortress of Caprarola was by Antonio San Gallo, who had much practice in engineering and military architecture. I do not consider that this circumstance at all detracts from the merit of Vignola's subsequent share of the design, for it must have acquired as much (if not more) skill, to adapt his palace to San Gallo's foundations, as to have originated the palace-fortress itself.

The plan is pentagonal, with bastions at the angles, and while thus partaking of a military character, the architecture of the elevation is civil and palatial. Terrace surmounts terrace, the one communicating with the other by noble wide flights of steps. The basement is raised upon its sub-basement, excavated from the solid bed of rock, while two beautiful orders, towering proudly above these masses surmount the pile. Grandeur and sublimity reign without; beauty, grace, and harmony preside within. Well, indeed, might old Daniel Barbaro exclaim, when the first view burst upon him, "*La presenza è maggior della fama.*"

The arrangement of the plan is a masterpiece of skill; the circular court one of the most charming and harmonious compositions ever devised. The spiral staircase, with its ascending stories of columns and pilasters, perhaps unrivalled in the world; and while we gaze in admiration at the expanse of mind which conceived so great a work, our eye, as well as our imagination and taste, are more than satisfied with the exquisite refinement and purity of the details. Many years have now passed since I saw this grand specimen of Italian architecture; but I have a most vivid recollection of the strong feeling of admiration it produced on myself and fellow travellers.

Giorgio Vasari, in his 'Life of Taddeo Zucchero,' has given a minute account of this celebrated building, describing the various apartments with their superb embellishments by the brothers Zuccheri and by Tempesta, as well as several perspective views by Vignola's own hand.

In Le Bas and Debret's work upon the edifices of Vignola will be found the most architectural account of Caprarola. Some of the decorative paintings are given by Do Prenner, in a fine work entitled 'Illustri Fatti Farnesiani;' and the plans and sections and elevations will be found also in Rossi's 'Studio d'Architettura Civile,' and in Percier and Fontaine's 'Maisons de Plaisance de Rome.' These celebrated French architects have also included the building in the grounds termed La Palazzina, the refined beauties of which are most elegantly and faithfully represented by them. The happy expression of Vasari with respect to the Villa Farnesiana at Rome, "*Non murato ma veramente nato,*" would in all respects apply to this Palazzina, one of the most exquisite creations of the refined taste and imagination of Vignola.

I have already made some mention of the part Vignola took in the designs for the Escurial; how far that gigantic royal convent has been erected according to the design furnished by our architect, it is difficult to say. The plan now exhibited belongs to Mr. Donaldson, who, following Milizia, attributes the design to Juan Battista di Toledo. It appears that the palatial bears but a small proportion to the ecclesiastical part of the edifice, which, as a whole, has not been unhappily described by Beckford as being "at once a temple, a palace, a convent, and a tomb."

Vignola has not merely instructed us by his executed works, but he has left a guide for all time in his admirable treatise upon our art. To him we are indebted for rules, proportions, and maxims, the result of a careful study of the architectural remains of ancient Rome; and, although this great master has founded his orders upon the antique models, he was no servile copyist or imitator, but proved himself as eminently successful in his original productions as he was in his adaptation of the remains of antiquity. His beautiful and original introduction of consoles connecting with the modillions in a crowning cornice has been frequently imitated in continental buildings, and in our own country by Wren, at St. Paul's, as well as by many other of our principal architects of the past and present day; his playful adaptation of ornaments over his doors and windows, and his ingenious and bold application of rustics, afford us examples of originality well deserving our attention and study.

In some valuable remarks on the genius of this great artist, I entirely concur with Mr. Cockerell, who has observed that "Vignola was sparing in the use of the orders, not lavishly employing them in a vulgar and common manner, but applying them rather as precious decorations to be tenderly and delicately treated; he relied much upon his door and window dressings, making his window openings extremely small, thus giving great breadth and scale to his façades. The introduction and treatment of rustics in his portones is most masterly, frequently uniting them with the stringcourse of the *piano nobile*. For his door and window dressings he stands unrivalled."

It is too much the fashion of the day to underrate the value of the study of Classic architecture and its revival under the great

Italian masters; some are for an extensive and nearly exclusive application of Mediæval architecture, while others are for forming a national style of our own, which should have the merit of "being something new." The acute and strong-minded Forsyth remarks upon this point, "I do not indeed admire the philosophy which has lately broken into architecture, nor the contempt so often affected for Vitruvius. I would not subvert the authority of example, nor be too severe upon the ancient superstitions of the art. Their very antiquity, if it does not satisfy our reason, has a charm on the fancy, and they fill up a space which our reverence for what is old would make it difficult for a reformer to fill up more pleasingly." And with equal force has it been observed by that most eloquent instructor of art, Sir Joshua Reynolds, "Invention is one of the greatest marks of genius; but if we consult experience, we shall find that it is by being conversant with the invention of others that we learn to invent, as by reading the thoughts of others we learn to think."

In these days we have every possible facility and inducement held out to us for the attainment of a thorough knowledge of our art. Upon the opening evening of our present Session, the Gothic architecture of Germany was graphically described and analysed by one of the first scholars of our times, the Master of Trinity College, Cambridge. Our Professor's chairs are filled by the most able instructors. We have excellent weekly and monthly publications affording us both scientific and practical information. Our museums are daily being enriched with sculptured remains from the most ancient cities in the world. We have societies devoting their time and energies to the publication of architectural stores which have hitherto been confined to the few, and nearly unknown. The wonderful architecture of Southern India has been brought to our view and described and commented upon in this room with the most profound learning: while the Oxford graduate steps forward with all the advantages of sound scholarship, intellectual mind, and poetical imagination, to enlighten us with his 'Seven Lamps of Architecture.'

My own impression is, that each different style has its distinct and separate beauties and features, and it is not by a blind adherence to one particular school for all purposes, but by a proper adaptation of the style we may select for the object to be attained, that we can command success.

I would not for one moment be supposed to detract in the slightest degree from the great merit of many of our rising architects in the admirable designs and structures they produce in imitation of the ecclesiastical and domestic architecture of our forefathers, and the experience of the last ten years has proved to us that their success progresses with their knowledge and research. A similar persevering study of Italian examples would no doubt produce similar satisfactory results; and as the brouch spire and the porch of the thirteenth century may not possibly be found suitable for every street or square in the metropolis, or in our provincial cities and towns, I should rejoice to see the studies of our young architects also directed to the spires of our own immortal Wren, to the cupolas of Brunelleschi and Michael Angelo, and to the works of my favourite Giacomo Barozzi da Vignola.

N.B. On referring to the several illustrations, Mr. Angell took occasion to acknowledge the obligation he was under to his brother Members, Mr. John Davies, Mr. Charles Parish, Mr. Edward Falkener, Mr. W. W. Deane, and Mr. H. Oliver; as also to Mr. James Morant Lockyer, Mr. F. B. Newman, Mr. E. Pritchard, Mr. Arthur Bakewell, and to his own pupils, Mr. George Judge, jun., and Mr. Henry Wood, for the valuable drawings, sketches, and many points of interesting information they had afforded him. Mr. Angell also took occasion to refer to a plan of Caprarola, belonging to Mr. Hardwick, made in 1778, by Mr. Thomas Hardwick, his late father, and Mr. Angell's most esteemed master and worthy instructor.

List of Popes during the Lifetime of Vignola, A.D. 1507 to 1573.

A.D.	Name.	Contemporary.
1503	.. Pius III.	Henry VIII. of England, 1509.
"	.. Julius II.	" "
1513	.. Leo X.	" "
1522	.. Adrian VI.	" "
1523	.. Clement VII.	" "
1534	.. Paul III.	" "
1550	.. Julius III.	Edward VI., 1547.
1555	.. Marcellus II.	"
"	.. Paul IV.	"
1559	.. Pius IV.	Mary, 1553.
1566	.. Pius V.	Elizabeth.
1572	.. Gregory XIII.....	"

Remarks made at the Meeting after the reading of the foregoing Paper.

Mr. ANGELL on concluding his paper, having been greeted with considerable applause,

Mr. TITE said he was desirous of putting language into those cheers, and therefore he would move a vote of thanks to Mr. Angell for his interesting and successful paper, which was equally complete as a memoir of Vignola, and as an illustration of his works. He had tried to find out if there were any circumstances relative to Vignola which were not generally known, and he had discovered, as well as Mr. Angell, that Vasari was jealous of Vignola, for he found very little about him under the head Barozzi, and under that of Vignola nothing at all. The great bulk of the information respecting Vignola in Vasari was given incidentally, and he broke off rather abruptly, saying he should say more about it in another place, but that other place was nowhere to be discovered. The struggles of Vignola to attain a position were as remarkable as the eminence which he succeeded in achieving. The gradual and laborious steps by which he rose to eminence, and his ultimate success and distinguished position, afford to young architects many an useful lesson of perseverance and hopefulness. Mr. Angell had early in life discovered the excellencies of his favourite, and he hoped that now later in life he would give the Institute a little more of the Italian architects of the 16th century. He agreed with his friend that this architecture, as applicable to ecclesiastical purposes, had of late been too much neglected. There was, he admitted a great deal of beauty and fitness of purpose in mediæval architecture, but admiration for that style might be carried too far. It might be considered an heretical opinion, but he believed that a church might be built for Protestant worship much better adapted for the purpose than many of the structures recently erected, beautiful although they undoubtedly were. He would say, let the latter be built, but do not let the Italian style be cast aside. He knew that fashion possessed imperative influences, and that to live the architect must in some degree obey the taste of the times; but he honestly thought that the neglect of the Italian for the mediæval, if carried much farther, would be a serious evil. Even now English architects had not progressed in their ecclesiastical buildings as they ought to have done. He hoped the elaborate and elegant essay they had just heard would revive in the minds of those present,—and he knew how much influence they exercised over the general taste of the community,—the study of Vignola. His object in rising was, however, to move that the ordinary compliment, offered in no ordinary sense, be given to his friend, as well as their sincere thanks for having delivered so elegant, so complete, and so useful a paper.

Mr. HARDWICK could not allow any other person to second the motion, for he had had the good fortune to be brought up in the same office with Mr. Angell. They had pursued their studies together, and when he saw the application, the zeal, the attention which his friend exhibited, he felt confident that sooner or later he would show great talent in his art. The paper that had just been read showed that he was perfectly right in his anticipations; for a more exquisite, a more charming essay on Italian architecture had never been written. He had visited many years ago the Caprarola of Vignola, in his opinion one of the most beautiful specimens of art in existence. He entirely concurred in the hope that this paper would bring back their students to a greater attention to the architecture of Italy. The architecture of the middle ages was beautiful and picturesque, and in many instances reached sublimity; but at the same time, some attention to the fine architectural taste and genius exhibited in the works of Vignola, and other Italian architects were essential to the student. He hoped every student present would allow the paper to make a due impression upon his mind, and that all of them would study the works of the Italian architects a little more than was now the practice.

The CHAIRMAN thought that young English architects would derive as much advantage from the study of Bramante and Vignola, as English painters derived from the examination of the great works of Michael Angelo and Titian. There was one expression which fell from Mr. Angell in his paper, in reference to which he wished to say a word or two. Mr. Angell spoke of the Italian style, a phrase perfectly justifiable by common parlance, but in his opinion extremely incorrect. The style of architecture in Italy was that which had prevailed ever since architecture had been civilised by Greece, greatly modified no doubt by political changes and social circumstances, and altered by the necessities of the times, and by the extended scope of the science of construction. Still it was essentially the same style; and it might be regarded (to take the mode of expression used in natural history), as a species belonging to a genus, which comprised Greek, Roman, Italian, and Modern architecture.

Mr. COCKERELL could not make up his mind to give a silent vote, although he would not repeat the compliments so due to Mr. Angell, which had been expressed by those, who had spoken for the whole sense of the Society. He joined in all those expressions of gratification, and also in the hopes which had been expressed for the revivification of the old masters, dug out from the remains of Italian architects as it were by this admirable paper, descriptive of one of those masters, not the least remarkable, interesting, and conspicuous in his career. He sincerely hoped that the works of the other great Italian architects of the 16th century would be presented to them in a similar manner; and by a comparative study of these "great lamps" of architecture, they should be able to appreciate the peculiar secrets and motives of progress which the art had made from Bramante, with his minute, silvery, delicate

modes of building, down to the peculiarly symmetrical structural idiom of Raffaelle. They would then be able to see how from one master to another what immense progress was made, and wherein was the secret by which the peculiar beauties of each were achieved. They saw by the admirable history which had just been read, how Vignola became an architect from being a painter; how he was a master of perspective because he was a modeller. Being a painter, he could amalgamate things which had not hitherto been incorporated, and thus he achieved a wonderful degree of progress in his architecture. He would remark casually as an instance of what he meant, that Vignola was the first to effect a combination between the arch and the column, and he united them in a manner altogether original, incorporating the keystone of the arch with the pilaster, so as to form one and the same structure. They all as good architects took care that it was so in fact; but they must admit the high merit of the man, who first made such a junction one of the beauties of architectural decoration. With regard to the great end of all proportion—magnitude—he apprehended Vignola attained that excellence by very extraordinary means. It was done simply by the smallness of his apertures. Indeed, the real magnitude was not nearly so surprising as its apparent dimensions; and thus they had here revealed one of the great secrets of architecture, how by the contrivance of proportions great magnitude might be obtained. The effects of the study of Vignola upon French architecture was apparent; the French confessed him to be their architectural saint, just as Palladio was our saint; and they had as great a number of beautiful translations of Vignola as we had of Palladio.

The vote of thanks was then passed by acclamation.

METEOROLOGY.

Sir—Your readers will agree with me that an importance, hardly to be estimated, attaches to the laws regulating the atmosphere which supplies us with the means of existence, surrounds us at all times, permeates our frame, and which conveys on wings unseen disease and death. Yet how few direct attention to the study of the phenomena of meteorology. Through the energetic exertions of James Glaisher, Esq., F.R.S., of the Royal Observatory, returns of observations, more or less elaborate, are obtained from between 30 and 40 stations in Great Britain. Observers remark, for the most part three times in 24 hours, the state of the barometer—the thermometer—the clouds and the wind, and register the quantity of rain daily. Mr. Glaisher receives by the electric telegraph the state of the atmosphere, and the direction of the wind, from various stations along the principal lines of railway at 9 a.m. daily; and from these data I have no doubt but that, in time, some valuable laws will be deduced in addition to those which he has already established.

I am anxious that scientific men should direct their attention to the subject of meteorology; and that amateurs who have time at their disposal should record observations in their own localities. If I thought it would interest your readers, I should be happy to describe such instruments as are adapted to the purpose; for, unless these are good and worthy of reliance, the time of the observer will be wasted and his observations useless.

I subjoin a table of certain meteorological results, from observations taken in various parts of England: the comparison of these will not, I apprehend, be without interest.

I am, &c.

John Drew.

Southampton, Feb. 14th, 1850.

Synoptical View of the Meteorology of various places in England, for 1849.

(Deduced from the Registrar-General's Reports.)

	Mean Pressure of dry Air, reduced to the Level of the Sea.	Mean Temperature.	Temperature of the Dew-Point.	Number of Days on which Rain Fell.	Amount Collected.	Degree of Humidity, complete Saturation being 1.
Guernsey ..	29·760	52·8	45·6	167	36·5	·812
Falmouth ..	—	51·8	—	185	44·5	—
Exeter	29·742	50·2	44·7	171	25·1	·808
Greenwich ..	29·882	49·8	43·9	163	23·6	·802
Aylesbury ..	29·823	49·2	42·8	157	27·	·791
Southampton	[illegible]	50·6	46·7	159	33·	[illegible]
Derby	29·732	47·4	42·6	190	26·5	·837
Liverpool ...	29·870	49·	43·9	—	30·5	·827
Stonyhurst ..	29·666	46·2	41·5	216	49·2	·840
Newcastle ..	29·814	47·1	42·7	148	35·4	·837

[We shall feel obliged if Mr. Drew will favour us with a description of such instruments as are adapted for the purpose, and we shall be happy to make our *Journal* the medium of such observations as Mr. Drew suggests.]

REPORT OF THE COMMISSIONERS APPOINTED TO INQUIRE INTO THE APPLICATION OF IRON TO RAILWAY STRUCTURES.

The Commissioners of Railways showed a vigilant anxiety for public safety and for the advancement of science, and greatly promoted both, when in August, 1847, they obtained the appointment of a Commission "for the purpose of inquiring into the conditions to be observed by Engineers in the application of Iron in Structures exposed to violent concussions and vibration."

The result of the labours of this Commission are now before us; and it is not too much to affirm that the present Report is almost, if not altogether, the most valuable public document extant relating to the science of engineering. For some time past the note of preparation for this work has been heard: we have had accounts of cabinet ministers being attracted by the magnitude and importance of the experiments, to examine them. More recently, Professor Willis has delighted a learned audience at Cambridge by the facility and simplicity with which he contrived to explain the most difficult subject on which he has been engaged as a member of the Commission; and the memoirs read by Professor Stokes, before the same academic body, have shown that the highest powers of mathematical analysis have been brought to operate upon and generalise results of experiments—to analyse and classify them—to group facts which were barren while isolated—to expand them, and give them the vitality—so to speak—of general principles.

The right method of pursuing investigations of this kind is this combination of theory and fact. The "practical man" is afraid of theory, and demands that all the rules for his guidance shall be deduced immediately from precedent alone. To this demand the simple reply is, that—desirable as it might be to comply with it—compliance is impossible. The requirements of actual railway construction are many and various—the means of experimenting few and restricted; so that, setting aside the question of expense, it would obviously be impracticable, in a reasonable duration of time, to furnish from observation a code of direct precedents for all the purposes of the engineer.

On the other hand, where experiments are undertaken for the judicious purpose of aiding theory, they should be carried out on such a scale as to leave no suspicion that they are mere toy-experiments—amusing illustrations of science made easy; and with this reflection, we cannot but observe with regret, that in several places in the work before us apologies are made on account of the limited means at the disposal of the Commission. From the importance of the inquiry, and the gravity of the events in which it originated, the public had a right to demand that the researches should not be impeded by ill-timed parsimony. Compare the scale of experiments on Railway Bridges with those on Government Ship-building! or, to make a more direct comparison—contrast the scale of the government experiments on Girders with those relating to the Tubular Bridges! It would be curious to calculate how many times the weight of metal in the magnificent model-tube experimented upon by Mr. Fairbairn at Millwall exceeded that of all the iron together employed in the researches of the Commission.

One advantage has, however, sprung from the restrictions complained of: they have served to show the immeasurable value of accurate scientific knowledge, and its power of extracting truth under difficult circumstances. The edict had gone forth: there must be no expenditure of public money on large castings of iron—*fiat experimentum in corpore vili*. But, notwithstanding, the Commission have succeeded in producing a body of sound invaluable information, as copious and accurate as was expected at their hands by those who anticipated that every facility would be afforded to them in the prosecution of their task. Unlearned investigators are apt to deduce from restricted experiments rules which will not bear the test of extended observation. In the present case, the happy combination of science and experimental skill displayed by Professors Willis and Stokes has averted this danger. However, it is important not only to deserve confidence, but to readily obtain it; and it is, therefore, much to be regretted that, if merely to satisfy the scruples of those who can only take facts just as they find them, more experiments on a large scale were not undertaken.

The Report and accompanying documents are comprised in a thick folio volume, of the well known blue-book form: a second volume consists of plans and plates. The Report itself extends over comparatively few pages. The other papers are principally as follows:—Appendix A. Experiments on Impact upon Beams, and on the tensile, compressive and transverse strength of Iron; Appen-

dix AA. Inquiries to supply data for the erection of the Tubular Bridges; Appendix B. An Essay by Professor WILLIS, on the deflection of Beams by travelling loads, with researches by Professor STOKES; Experiments on the same subject, by Captain JAMES and Lieut. GALTON; also on statical pressure and slowly-moving weights; Evidence by eminent engineers; Replies to circulars sent to Iron-masters and Iron-founders; &c.

The plates in the second volume are illustrative of the several kinds of experiments, and include elevations and details of a very considerable number of important railway bridges.

The Report commences with a notice of the contrariety of opinions respecting the effects of travelling weights on girders—some engineers thinking one-third, and some no more than one-tenth the statical breaking weight, the greatest load which the structures could safely bear. It is stated, that in the course of the inquiry, it appeared "that the effects of heavy bodies moving with great velocity upon structures had never been made the subject of direct scientific investigation." This may be true as regards publication before the *commencement* of the inquiry by the Commission; but very shortly afterwards, and long before the publication of the present volumes, the paper (which is noticed in it at page 213, by Professors Willis and Stokes, with approbation) "on the Dynamical Deflection and Strain of Railway Girders," appeared in the number of this *Journal* for September, 1848.

In the experiments of the Commission, velocity had considerable effect in increasing deflection. It is, however, important to know that the conclusion is not extended to practice. The results of the inquiry thoroughly confirm the conclusion stated in this *Journal*, that in real railway girders the deflection is *inconsiderably increased by the velocity of the transit of a train*. The reason that the experiments apparently vitiate this conclusion is admirably elucidated by Professors Willis and Stokes. For the present, it is sufficient to observe that the increase of deflection in the experiments arose from the smallness of the mass of the beams compared with that of their loads.

An apparent inaccuracy as to the history of the Laws of Elasticity occurs in Appendix A, given in another part of this *Journal** :—

"Dr. Hooke's law, expressed by him in the phrase '*ut tensio sic vis*,' is not, perhaps, accurately true in any material. Its deviation from truth in cast-iron, under every degree of strain, even the smallest, was first shown by experiments made by the author, and reported in the sixth volume of the *Transactions* of the British Association for the Advancement of Science. In his subsequent researches on the elasticity of various materials, it was shown that this defect was considerable in stone and other crystalline bodies tried, and existed in a less degree in wrought-iron, steel, timber, and laminated substances."

The inexactness of "Hooke's law" was shown about 100 years before any member of the Commission was born, and by no less a person than James Bernouilli. In the *Acta Eruditorum* of Leipsic, for 1694, he gives investigations of the elastic curve—1, generally when the elastic forces follow any law whatever; 2, when they vary as any power of the extension; 3, when they are directly proportional to the extension. The latter investigation he prefaces by saying†—

"The common hypothesis, as I have just said, is, that *the extensions are proportional to the stretching forces*, which was formerly adopted by the celebrated Leibnitz, in his most ingenious research respecting the *Resistance of Solids;* and by myself in the present subject, before that I arrived at the general construction of the problem. I therefore consider it worth while to explain a little more particularly the nature and properties of our Curve on this hypothesis; although I am very unwilling to contend for the precise truth of this hypothesis, or of any other, being persuaded, rather, that no constant law of tensions is observed in nature but that it differs according to the different texture of bodies. This is seen to be abundantly confirmed, both by my own and other persons' experiments, of which a great part are industriously collected by the author, whom I have already commended [Franciscus Tertius de Lanis] in the above quoted treatise, *Magisterii naturæ et artis*."

* See Journal, page 66.

† Vulgaris (ut modo dixi) est hypothesis extensiones viribus tendentibus proportionales esse: quâ et usus olim celeberrimus Dr. Leibnitius in acutissima sua lucubratione de Resistentia Solidorum; et ip semel ego in presente materia, prius quam generalem problematis constructionem adveniasem. Quapropter operæ pretium existimo, naturam et proprietates curvæ nostræ in hac hypothesi paulo specialius exponere: quanquam pro ipsa hypotheseos hujus, sicut et pro cujusve alterius, veritate nentiquam militare nolim, persuasum potius habens, nullam constantem tensionum legem in natura observari, sed eam pro diversa corporum textura diversam existere, id quod experimenta tum nostra, tum aliorum, abunde confirmare videntur, quorum plurima prælaudatus Author industrius "Magisterii naturæ et artis" loco cit recensct.—p. 270-1.

There seems no reason to suppose that an exact mathematical law of elastic tension can exist, or that a law which expresses the extension by the first, or first and second, powers of the tension, can be otherwise than approximate. With respect to many forces existing in nature, there can be no such antecedent objection to an exact mathematical law. For central forces, such as the sun's attraction, we may readily suppose *a priori* that the law may be that of the inverse square, because if the attraction be supposed to radiate into space, like light, the concentric spherical surfaces over which it is diffused vary in magnitude as the square of their radii. But with regard to the cohesive force of particles in contact, there can be no such regularity of operation. The tensile powers of a piece of stone or iron are affected by its heterogeneity, crystallisation, lamination, porosity, chemical affinities, temperature, &c. Now, in discovering a law of tension from experiment, all these irregularities are "lumped" together, and we strike an average of their effects.

If, as in some of the experiments before us, twenty different weights be applied to stretch in different degrees the same rod, a theoretical law involving first and second powers only, will slightly disagree with each of the twenty experimental results. We must, therefore, suppose either the law or the experiments, or both, to be inexact. If the experiments exhibited perfect accuracy (though this is never attainable), the law must not stop at the second power, but be continued to the twentieth; for there will be twenty equations to determine twenty unknown quantities—namely, the co-efficients of the twenty powers. A formula involving the first four powers is given in a note, page 113.

We observe with pleasure a notice of the efficient assistance which Mr. Tredgold, son of the late celebrated writer of the 'Treatise on the Steam-Engine,' rendered in the course of this experimental inquiry. In addition to a great amount of numerical computation and experimental observation, he prepared several excellent drawings illustrative of the experiments, and appearing with his name in the second volume.

It will be remembered, that some surprise was occasioned by the publication in the recent edition of Dr. Gregory's 'Mechanics for Practical Men,' of the results of some experiments giving higher values for the tensile strength of cast-iron than have been hitherto generally adopted. This subject has been again referred to careful observation; and an explanation, which seems correct, is given of the too high values of the tensile strength obtained by Mr. Thomas Cubitt—namely, that he used a hydraulic press to test the iron, and that this machine is apt to give exaggerated results. Experiments have also been made, to determine whether the tensile strength be greater for cruciform than for circular or rectangular sections of the rod. It appears that the strength per square inch of section is a little (but only a little) stronger for the cruciform section, the excess of strength being attributed to the metal being harder in the thinner sections than others. We may here remark, that for a similar reason the strength per square inch, of circular sections for example, is probably somewhat affected by the magnitude of the section. On account of irregularities of casting and cooling, it is probable that a circular rod 4 square inches in area, would not be exactly twice as strong as a similar rod of 2 square inches area.

Only one beam exceeding 15 feet in length appears to have been used; and this was supplied not by government, but by private persons. It was 48 feet long; and one of several girders intended for a bridge across the river Irwell. Lieutenant Galton, the indefatigable secretary of the Commission, assisted at this experiment.

In order to notice all the statical experiments together, we proceed to refer to experiments by transverse pressure on rectangular beams, made by Captain James at Portsmouth. The most remarkable of these experiments were on ¾-inch bars *planed out of the centres of 2-inch square and 3-inch square bars.*

These experiments, like the preceding, show that the deflection increases from the commencement of each experiment somewhat more rapidly than in proportion to the transverse pressure. Experiments were also made by means of the hydraulic press on the effect of tension bars attached along the under sides of the bottom flange of cast-iron girders. The mean of several experiments on girders 9 feet between the supports, gave the breaking weight with the tension bar rather greater than without it; and similar results were obtained from girders with the upper flange arched. These experiments were not, however, followed out (from "want of time and *limited means*" again!) so far as was deemed desirable.

Our notice of other parts of the inquiry we reserve for future consideration.

APPENDIX (A) TO REPORT ON IRON.

By EATON HODGKINSON, Esq. F.R.S.

The following series of experiments was conducted by the author, partly in London, and partly in Manchester. The description and tabular results of the whole are given in this Appendix, with such general conclusions from them, as the limited period of the time of preparing the results for the press permitted.

In accordance with the instructions under which the Commissioners acted, the experiments were directed principally (though not wholly) to determine the effects of impacts and vibrations upon iron. Several distinct classes of experiments have therefore been undertaken, for the purpose of exhibiting the properties of cast-iron, in particular, when subjected to different mechanical tests, and the numerous tables appended will show the extent and variety of these inquiries.

An extensive experimental inquiry, not yet published,* had been recently concluded by the author, of which the object was to determine the mechanical conditions to be observed, in the construction of the tubular bridges across the Menai Straits and the Conway.

Among other results, it was ascertained that a great saving of metal for an assigned degree of strength might be effected by employing cast-iron longitudinal ribs in the top of wrought-iron tubes. It seemed, therefore, very desirable to ascertain for the purpose of this Commission, whether, and in what manner, the combination of wrought and cast-iron might be advantageous in trussed girder bridges. For such experiments, peculiar facilities existed, as they might have been made with apparatus of a very complete and costly description, which had been constructed for former experiments on the strength of materials, and much extended for those on tubular bridges.

Of the latter, some of the models experimented upon were large, and varied in weight from three to seven tons. Had experiments on trussed girders of half that weight at least, been made, it is probable that valuable conclusions, directly applicable to the practice of engineering, might have been obtained. The expense attendant on such experiments would, however, have been great, and the limited extent of the grant to the Commission, rendered it necessary to confine the inquiries [illegible] those subjects on which a knowledge of fundamental principles was most required. It became then a matter of careful consideration to devise the experiments in such a manner that their practical utility might be as little as possible affected by the restriction referred to, as the scale of the experiments did not always permit direct and immediate comparison, with the actual practice of railway construction.

The experiments were therefore conducted, so as to obtain principally those scientific data, which appear to be most required for completing the mechanical theory of elastic beams.

Defect of Elasticity.

In any general investigation of the properties of elastic beams, the powers of the material to resist direct tension and compression are necessary data. If a beam be in any manner bent, its concave side will be compressed, and its convex side extended. The material is, consequently, subjected to both tensile and compressive forces; of which, therefore, an exact knowledge must precede any accurate general theory of the laws of deflection, vibration, and rupture.

The longitudinal compression and extension of iron within certain limits are usually assumed to be directly proportional to the external forces by which they are respectively produced. The law is known by the name of Doctor Hooke, the first proposer of it, and has generally been made the basis of mathematical investigations respecting the deflection and strength of loaded beams.

Doctor Hooke's law, expressed by him in the phrase "*ut tensio sic vis*," is not, perhaps, accurately true in any material. Its deviation from truth in cast-iron, under every degree of strain, even the smallest, was first shown by experiments made by the author, and reported in the sixth volume of the *Transactions* of the British Association for the Advancement of Science. In his subsequent researches on the elasticity of various materials, it was shown that this defect was considerable in stone, and other crystalline bodies tried; and existed in a less degree in wrought-iron, steel, timber, and laminated substances.

It is a necessary consequence of the ordinary law of elasticity that the deflection of a horizontal beam by a vertical pressure should be directly proportional to that pressure. This conclusion, as might be expected, does not, however, coincide with experiments on beams of those materials, of which the elasticity has been above stated to differ considerably from that assigned by Doctor Hooke's law.

As the law of elasticity constitutes the very basis of all sound knowledge of the statical and dynamical properties of girders, the revision of that law, with respect to cast-iron at least, became, in the author's opinion, an indispensable requisite in the present inquiry. He, therefore, obtained liberty to make some experiments on the extension and compression of rods of iron, in order to deduce from them, if possible, the general relations between the weights and the changes of length produced.

To numerous experiments respecting impacts, occupying 27 tables, and to others made to determine the direct tensile and crushing strength of irons, not previously tried—besides some of smaller magnitude—the following experiments are added:—

1st. To determine with precision the direct longitudinal extensions and compressions of long bars of cast and wrought-iron, by weights varied by equal increments, up to that producing, or nearly producing fracture.

2nd. To seek for general formulæ, connecting the weights with the corresponding longitudinal tensions and compressions of cast-iron, and likewise, if practicable, with the "sets," or permanent alterations of the length of the rods remaining after the removal of the external forces: in order that the former may be directly applied to the determination of the situation of the neutral line, and the strength of cast-iron beams of every form of section.

3rd. To determine with equal precision, the deflection of horizontal bars produced by various transverse pressures, and to compare the effects with those produced by impacts.

4th. To seek for general formulæ connecting the transverse pressure, the deflection, and the set remaining after the pressure was removed.

The great defect of elasticity of cast-iron, and particularly as compared with that of wrought, may be rendered very obvious by the results of the experiments on each of the irons, with respect to extension, compression, and transverse flexure.

The theories in common use, at the present time, proceed on the supposition, that bodies strained are perfectly elastic; and therefore the extensions, compressions, and transverse flexures are assumed to be, within certain limits, as the forces producing them. Thus, $w =$ the weight applied to stretch a body, and $e =$ the extension produced by that weight, the ratio $\frac{w}{e}$ ought to be constant with different weights laid on the same bar, and it will be found much more nearly so in wrought-iron, than in cast, but in neither strictly so. If, in like manner, w^1 be the weight applied to compress a bar, and d the decrement of length it has sustained, $\frac{w^1}{d}$ ought to be constant, but there will be a falling off, analogous to the last, in cast-iron particularly. In the transverse flexures of bars, if w_1 represent the weight laid on, and d the deflection produced, $\frac{w_1}{d_1}$ ought to be constant, but the falling off will be as in the preceding cases.

Formulæ for the Resistance of Bars to Horizontal Impact.

In an experimental inquiry by the author, into the power of beams to sustain impact from a body striking them horizontally, or falling directly upon them, it was shown that if blows of the same magnitude were given upon the middle of a beam, either by elastic or inelastic bodies of the same weight, the same effect would be produced. The striking body appears to proceed with the beam after impact, as if they were one mass.—(5th Report of the British Association, 1835.)

In the inquiry above, formulæ were deduced according to these conclusions, both for horizontal and vertical impacts, taking into consideration the effect of the weight or inertia of the body struck.

Formulæ for horizontal impacts are comparatively simple, and that given below is the same as that of Tredgold.—(Essay on the Strength of Iron, Art. 302.)

$$\frac{h w^2}{w + w'} = \frac{p e}{2}$$

where $w =$ the weight of the striking body, $h =$ the height due to the velocity of the impact, $p =$ a pressure which applied gradually to the middle of the beam, would bend it to an extent equal to that produced by the impact $e =$ the deflection caused by that pres-

*The work here mentioned appears in the Report, under the designation of Appendix AA.

sure, and $w' =$ a weight equivalent to the resistance of the beam, from its inertia.

If the resistance of the body struck had been uniform, the right side of the equation would have been twice as great, or $p\,e$; but in a beam, the resistance to flexure is nothing in the commencement, and it increases in proportion to the flexure.

The preceding formula gives the impact, in terms of the height fallen through by the ball or striking body; but, in the experiments, the deflections are given in terms of the chord of the arc of impact, and the following formula would represent them.

$$d = wc\sqrt{\frac{e}{p'\,r\,(w + w')}}$$

where $d =$ the deflection of the beam, $c =$ the chord of the arc, $r =$ the radius, from the point of suspension to the centre of the ball, $p' =$ any pressure applied to bend the beam, $e' =$ the deflection caused by that pressure, and the rest as before.

The value of w' depends upon the weight of the beam, and as a mean, it may be taken at one half of the weight of the beam between the supports, as was shown by the experiments in the Report above-mentioned.

Objects of the Tables of Experiments, with some of the Results arrived at.

Tensile and Crushing Strength of Cast-Iron.—Tables I. to V. These experiments were made to ascertain the direct tensile and crushing strengths of several denominations of cast-iron in common use, but of which these properties had not been [redacted] all determined, or very imperfectly. The irons of which the tensile force was determined, were 17, and the crushing force of all these irons was also obtained.—(See Abstract, No. I.)

Transverse Pressure on Bars, very long and flexible.—Tables I. to VI. contain results on the *transverse strength* and resistance of very thin flexible bars, by forces acting horizontally, the ends of the bars being supported on friction rollers. The experiments were made to exhibit very fully the deflections and sets of cast-iron, and the defect of its elasticity; in order to throw light on the great deviations in this metal, from computations according to the theories in common use; and to explain anomalies in some of the results of the other parts of this inquiry. Thus, by showing that *defect of elasticity*, the cause of these anomalies, *was nearly as the square of the deflection*, it was rendered probable that the value of the weight might be expressed in terms of the difference between the 1st and 2nd powers of the deflection, instead of the 1st power alone, on which it had been assumed by previous authors to depend. This being tried, was found to give results differing but little from those of the experiments, as may be seen by turning to the tables. Formulæ for the weights and sets, in terms of deflections, were obtained.

Long-continued Impact upon Bars of Cast-Iron.—Tables I to IV. are on the effects of *long-continued impact*, applied horizontally, upon the middle of the beams, to ascertain to what degree beams or beam bridges might be successively deflected, by impacts and vibrations, to resist fracture for any length of time. As an abstract of the results of these experiments is given, they will not be further noticed here, except to mention that *it is scarcely safe to bend beams constantly to one-third of their ultimate deflection, and that they ought not to be loaded to more than one-sixth of their breaking weight laid on rapidly.*—(See Abstract, No. II.)

Horizontal Impact upon Bars of Cast-Iron.—Tables I. to III. show that bars of various forms of section, but of equal weight, offer the same resistance to impact when struck by the same ball. Thus a bar 6 × 1½ inches in section, placed on supports 13 feet 6 inches asunder, required the same magnitude of blows to break it in the middle, whether it was struck on the broad side or the narrow one; and these blows were required to break a bar, the section of which was 3 × 3 and the length the same. The main object of these experiment was to furnish data for a correct theory of the resisting power of bars to impact.—(See Abstract, No. III.)

Impact on Bars of Wrought-Iron.—Another course of experiments was tried, to ascertain the effects of horizontal impacts upon bars of wrought-iron, to compare together the results from pressure and impact, and to obtain the resistance of the bar from its own weight.

In these the deflections produced by a ball suspended with a constant radius, were nearly as the chord of the arc through which it was allowed to fall, to strike the beam at the bottom of the arc. In other words *the deflection of the beam was nearly as the velocity of impact*, since the velocity varies as the arc. The deflection in cast-iron bars is greater than in proportion to the velocity.

Vertical Impact on Loaded Bars.—On the effect of vertical impacts on loaded bars of cast-iron.

These experiments show, that beams loaded to a certain degree, with weights attached to them, and spread over their whole length, so as not to prevent the flexure of the beam, resisted greater impacts from the same body falling on them, than when the beams were unloaded, in the ratio of 2 to 1. For other particulars, and a property connecting the velocities of impact and deflections, see Abstract, No. IV.

On the Extension of Cast-Iron Bars.—The experiments of this class were made on bars one inch area of section nearly, and 50 feet long. They were suspended vertically from the top of a high building, and had weights attached to the bottom; the weights were varied by small increments, until the bar broke; the extension and set, with every change of weight, were obtained with great care. The results being afterwards reduced to what they would have been, if the length had been 10 feet, and the area of a section 1 square inch.

From these, formulæ were obtained connecting the weights with the extensions.

On the Compression of Cast-Iron Bars.—Tables I. to VI. contain results of experiments on the compressions of bars of the same irons, 10 feet long and 1 inch square; together with formulæ connecting the weights and the compressions produced by them.

The results, both of extension and compression of cast-iron, have been adapted to any length l at pleasure, in order that they might be applied to determining the transverse strength of a beam of cast-iron, on more correct principles than those hitherto used, and they have also been adapted to the formulæ for the strength of beams given in a work formerly published by the author, entitled, 'Experimental Researches on the Strength and other Properties of Cast-Iron.'—(See Abstract, No. V.)

On the Compression of Short Cylinders of Cast-Iron of Various Kinds.—These experiments contain the decrements in parts of the length, with different weights, up to the crushing weight.

Transverse Strength of Bars and Beams.—Tables I. to X. are on the transverse strength of square bars of Blaenavon Iron, No. 2, of which the lengths were 15 feet, 10 feet, and 5 feet, and the sides of the square 3, 2, 1 inches respectively; with some other bars of different kinds of iron.—(See Abstract, No. VI.)

Table XI. The experiment in this Table, is on the strength of a large beam of cast-iron, the distance between the supports of which was 45 feet, and the depth 28½ inches; the breaking weight being 54 tons nearly.

The great labour of an inquiry of this nature, both in making the experiments and in adapting them to their intended purpose, requires the union of much time and many hands; and the author has great pleasure in acknowledging the efficient services derived from one who has been engaged in the matter nearly from the commencement, Mr. Thomas Tredgold, the son of the late eminent writer on these subjects.

Abstract No. I.

Tensile and Crushing Strength of Cast-Iron.

Results of Experiments *to determine the ultimate Tensile and Compressive, or Crushing Forces, of various denominations of Cast-Iron in common use; these qualities not having been previously obtained in the Irons tried.*

The experiments are given at large in Tables I., IV., and V. In obtaining the tensile strength in Table I. the form of the castings

was that of a cross; or that which had been employed in all the published experiments of the author. And to show that this was

as good, if not better than other forms, besides being, as believed, less liable to theoretical objections than others, experiments were made upon castings with rectangular and circular sections. These experiments are in Table II., and the results from the cruciform section were in all the sound castings somewhat higher than those from the other sections.

In Table I. the specific gravities of 17 kinds of iron are given; they are obtained both from the thickest and the thinnest parts of the castings torn asunder.

Description of the Iron.	Tensile Strength per square Inch of Section.	Depth of Specimen.	Crushing Strength per square Inch of Section.	Ratio of the Powers to Resist Tension and Compression.	
	lb. tons.	in.	lb. tons.		Mean.
Low Moor (No. 1)	12694 or 5·667	½ 1½	64534 or 28·809 56445 or 25·198	1 : 5·084 1 : 4·446	1 : 4·765
Low Moor (No. 2)	15458 or 6·901	½ 1½	99525 or 44·430 92332 or 41·219	1 : 6·438 1 : 5·973	1 : 6·205
Clyde (No. 1)	16125 or 7·198	½ 1½	92869 or 41·459 88741 or 39·616	1 : 5·759 1 : 5·504	1 : 5·631
Clyde (No. 2)	17807 or 7·940	½ 1½	109992 or 49·103 102030 or 45·549	1 : 6·177 1 : 5·729	1 : 5·953
Clyde (No. 3)	23468 or 10·477	½ 1½	107197 or 47·855 104881 or 46·821	1 : 4·568 1 : 4·469	1 : 4·518
Blaenavon (No. 1)	13938 or 6·222	½ 1½	90860 or 40·562 80561 or 35·964	1 : 6·519 1 : 5·780	1 : 6·149
Blaenavon (No. 2, first sample)	16724 or 7·465	½ 1½	117605 or 52·502 102408 or 45·717	1 : 7·032 1 : 6·123	1 : 6·577
Blaenavon (No. 2, second sample)	14291 or 6·380	½ 1½	68559 or 30·606 68532 or 30·594	1 : 4·797 1 : 4·795	1 : 4·796
Calder (No. 1)	13735 or 6·131	½ 1½	72193 or 32·229 75983 or 33·921	1 : 5·256 1 : 5·532	1 : 5·394
Coltness (No. 3)	15278 or 6·820	½ 1½	100180 or 44·723 101831 or 45·460	1 : 6·557 1 : 6·665	1 : 6·611
Brymbo (No. 1)	14426 or 6·440	½ 1½	74815 or 33·399 75678 or 33·784	1 : 5·186 1 : 5·245	1 : 5·216
Brymbo (No. 3)	15508 or 6·923	½ 1½	76133 or 33·988 76958 or 34·356	1 : 4·909 1 : 4·963	1 : 4·936
Bowling Iron (No. 2)	13511 or 6·032	½ 1½	76132 or 33·987 73984 or 33·028	1 : 5·635 1 : 5·476	1 : 5·555
Ystalyfera, anthracite (No. 2)	14511 or 6·478	½ 1½	99926 or 44·610 95559 or 42·660	1 : 6·886 1 : 6·585	1 : 6·735
Ynisceadwyn, anthracite, (1)	13952 or 6·228	½ 1½	83509 or 37·281 78659 or 35·115	1 : 5·985 1 : 5·638	1 : 5·811
Ynisceadwyn, anthracite, (2)	13348 or 5·959	½ 1½	77124 or 34·430 75369 or 33·646	1 : 5·778 1 : 5·646	1 : 5·712
Mr. Morries Stirling's, denominated 2nd quality	25764 or 11·502	½ 1½	125333 or 55·952 119457 or 53·329	1 : 4·865 1 : 4·637	1 : 4·751
Mr. Morries Stirling's, denominated 3rd quality	23461 or 10·474	½ 1½	158653 or 70·827 129876 or 57·980	1 : 6·762 1 : 5·536	1 : 6·149

Abstract No. II.—Collisions and Vibrations.

Power of Beams of Cast-Iron to sustain long-continued Impact.

The effect of impact and vibration upon structures, was a leading object of inquiry with the Commission; and the first series of experiments instituted upon this subject was, to determine the power of beams to sustain impacts many times repeated. For this purpose, 16 bars were cast, all from Blaenavon Iron, No. 2, and five at least of the 16 were found to be slightly defective at some place where they gave way. Whether these small defects were more numerous than would be found in practice, it would be difficult to determine.

Six of the bars were each 15 feet long and 3 inches square, and placed on supports 13 ft. 6 in. asunder; seven were each 10 feet long and 2 inches square, and 9 feet between the supports; and three were each 5 feet long, 1 inch square, and 4½ feet between the supports. Of these bars, six were bent through ⅓rd of their ultimate deflection at each blow, and five of them bore each 4000 blows without breaking; the sixth was broken at a flaw with 1085 blows. One large bar, bent by impact through $\frac{5}{12}$ths of its ultimate deflection, was broken at a defective place with 1350 blows.

Of six bars bent by blows through half their ultimate deflection, five were broken with less than 4000 blows each; one with 29; one with 127, &c. The only bar which bore the 4000 blows was one of the smallest kind, or 1 inch square.

Of three bars, one bent to $\frac{7}{12}$ths, and two to ⅔rds the ultimate deflection; all were broken; the two latter with 127 and 474 blows respectively; the former required 3700 blows to break it.

Of ten bars of Low Moor Iron No. 2, each 10 feet long and 2 inches square, placed on supports 9 feet asunder, and struck in the middle with long-continued impact, as before, four broke at defective places, and two at sound ones. Three were subjected to impacts, bending them through ⅓rd of their ultimate deflections, and bore the test without fracture; of three bent by blows through half their ultimate deflection, two were broken; those bent through ⅔rds were all broken.

On the whole, it appears that no bar but one, and that a small one, stood 4000 blows, each bending it through half its ultimate deflection; but all the bars, when sound, stood that number of blows, each bending them through ⅓rd their ultimate deflection. It must, however, be borne in mind that a cast-iron bar will be bent to ⅓rd of its ultimate deflection with less than ⅓rd of its breaking weight laid on gradually; and ⅙th of the breaking weight laid on at once, would produce the same effect, if the weight of the bar was very small compared with the weight laid on it. Hence the prudence of always making beams capable of bearing more than six times the greatest weight which will be laid upon them.

Transverse Strength *to resist long-continued Impact from Balls striking* horizontally *against the middle of Bars, the Balls acting as Pendulums with a radius* (r) *of* 17 ft. 6 in.

The bars were cast of three sizes—viz.: 15 feet long and 3 inches square; 10 feet long and 2 inches square; and 5 feet long and 1 inch square. A thin piece of lead, varying from 2 lb. to 4 lb. weight, was generally attached to the side of the bar where struck, to prevent injury to its surface by the impact.

Sixteen Bars of Blaenavon Iron No. 2.

Distance between the Supports.	Side of Square of Bar, nearly.	Weight of Striking Ball.	Assigned Deflection in terms of the ultimate Deflection.*	Number of Blows given to the Bar.	Effect on Bar
	Inches.	lb.			
13 ft. 6 in.	3	151½	[illegible]	1085	Broken.†
	3	151½	[illegible]	4000	Not broken.
	3	603	[illegible]	4000	Not broken.
	3	603	[illegible]	1350	Broken.†
	3	151½	[illegible]	127	Broken.
	3	608	[illegible]	3026	Broken.
9 feet.	2	75½	[illegible]	4000	Not broken.
	2	603	[illegible]	4000	Not broken.
	2	75½	[illegible]	29	Broken.†
	2	75½	[illegible]	1282	Broken.†
	2	603	[illegible]	3655	Broken.†
	2	75½	[illegible]	127	Broken.
	2	603	[illegible]	474	Broken.
4 ft. 6 in.	1	75½	[illegible]	4000	Not broken.
	1	75½	[illegible]	4000	Not broken.
	1	75½	[illegible]	3700	Broken.†

* The ultimate deflection was obtained from the Experiments on Transverse Pressure.
† Bars slightly defective.

Ten Bars of Low Moor Iron, and one of a mixture of Wrought and Cast Iron.

These bars were cast to be 10 feet long and 2 inches square; they were placed on supports 9 feet asunder. The radius (r) of the pendulum was 17·208 feet when the weight of the striking ball was 603 lb.; and 18·208 feet when the weight of the striking ball was 151½ lb.

Side of Square of Bar nearly.	Weight of Striking Ball.	Assigned Deflection in terms of the ultimate Deflection.	Number of Blows given to the Bar.	Effect on Bar.
Inches.	lb.			
2	603	[illegible]	4000	Not broken.
2	603	[illegible]	4000	Not broken.
2	603	[illegible]	608	Broken.[1]
2	603	[illegible]	182	Broken.[2]
2	403	[illegible]	175	Broken.
2	603	[illegible]	79	Broken.[3]
2	151½	[illegible]	440	Not broken.
2	151½	[illegible]	400	Not broken.
2	151½	[illegible]	102	Broken.[4]
2	151½	[illegible]	35	Broken.
2	608	[illegible]	3720	Broken.[5]

1 Slightly defective on one side.
2 Rather defective on the convex side.
3 Slight defect or discolouration on the convex side.
4 The bar broke about 3½ inches from the centre, where there was a defect on the convex side, ¼ inch area.
5 Mixture of wrought and cast iron.

Abstract No. III.—Synopsis of some of the principal results in the 19 Tables of Experiments on the effect of Horizontal Impacts upon Cast-Iron Beams, together with the Breaking Weights and Ultimate Deflections of Beams of the same size, as obtained from Tables I. to VI. *on Transverse Pressure by Vertical Force, and* Table. VI. *on Long Flexible Bars bent by Horizontal Pressure.*

The results set down are means from all the Experiments of each class, and the number of those Experiments is given in Column 2.

Number of Table.	Number of Experiments from which the results are derived.	Distance between the supports.	Dimensions of Bar in direction of Impact.	Dimensions of Bar perpendicular to Impact.	Weight of Bar between the Supports.	Weight of the Striking Ball (Radius, 17¼ feet).	Ultimate Deflection.	Ultimate Chord of Arc of Impact.	Ultimate Vertical Descent of the Ball.	Ultimate Work done by the Ball.	Breaking Weight of a similar Bar, by Transverse Pressure applied Horizontally.	Corresponding Ultimate Deflection by Horizontal Pressure.	Breaking Weight of a similar Bar by Transverse Pressure applied Vertically.	Corresponding Ultimate Deflection by Vertical Pressure.
		Ft. In.	Inches.	Inches.	lb.	lb.	Inches.	Inches.	Feet.		lb. Mean	Inches. Mean	lb.	Inches.
I.	2	13 6	3·045	3·0355	377·925	603	4·93 and 4·875 from the sound bar.	76·5 and 79· from the sound bar.	1·236	746·81	2885 } 2898 2912 }	4·939 } 4·76 4·59 }	2885 from 2 experiments, or 2853 previous to the reduction of the results to those of a bar 3 in. square.	4·6253 from 2 experiments, or 4·5505 previous to the reduction of the results.
II.	2	13 6	1·53	6·122	381·075	603	9+	78·	1·3071	727·69	.. ..	.. ..	.. ..	.. ..
III.	2	13 6	6·095	1·535	353·975	603	2·4 nearly.	80·	1·279	783·81	.. ..	.. ..	.. ..	.. ..
IV.	4	6 9	3·	3·	183·56	603	1·38	36·75	·6399	385·32	8267	1·311	6117 from 3 experiments, or 6440 from bars as cast, or previously to reduction of results.	1·2916 from 3 experiments, or 1·2722 from bars, results not reduced.
V.	2	6 9	1·49	6·095	186·575	603	2·4375	52·75	·5321	332·916	.. ..	.. ..	.. ..	.. ..
VI.	3 struck at the quarter-span	6 9	3·	3·	185·083	603	1·125	60·833	·8861	534·32	.. ..	.. ..	.. ..	.. ..
VII.	2	6 9	3·	3·	189·41	151½	1·2658 and 1·3125 from the sound bar.	138·5 and 142· from the sound bar.	3·697 and 4·001 from the sound bar.	559·17 and 605·[illegible] from the sound bar.	.. ..	.. ..	.. ..	.. ..
VIII.	4	9 0	2·012	1·966	186·96	603	3·125	39·9	·3159	190·481	1274, 2 inch square exactly.	2·981	1229 from 4 experiments.	2·654 from 4 experiments.
IX.	3	9 0	1·079	2·92	168·15	151½	2·67 and 2·75 from the sound bars.	72·63 and 80·5 from the sound bars.	1·2408 and 1·2856 from the sound bars.	187·671 and 194·447 from the sound bars.	.. ..	.. ..	.. ..	.. ..
X.	3	9 0	1·974	2·001	164·39	75¾	2·833	124·	3·0508	230·32	.. ..	.. ..	.. ..	.. ..
XI.	9 (2nd melting).	9 0	1·9906	1·975	166·62	151½	2·75	93·25	1·7244	260·363	.. ..	.. ..	.. ..	.. ..
XII.	3	4 6	2·	2·	44·	603	·7812	29·3	·1764	102·75	.. ..	.. ..	.. ..	.. ..
XIII.	4	4 6	2·	2·	44·	75¾	·697	86·3	1·925	145·257	.. ..	.. ..	.. ..	.. ..
XIV.	3	9 0	1·033	2·048	47·13	75¾	3·09	85·	1·4334	106·228	463 from bars before reduction of results, 416 from bar reduced to exact size from 9 experiments	5·954, 6·227, reduced from 3 experiments.	.. ..	.. ..
XV.	3	4 6	1·	2·	19·6	37¾	.. ..	70·	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
XV*.	3	4 6	2·	1·	19·6	75¾	.. ..	71·67	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
XVI.	2	4 6	1·0675	1·0945	13·165	75¾	1·66	32·4	·5309	41·29	447	1·669	440 from 3 experiments.	1·779 from 3 experiments.
XVII. Low Moor, No. 2.	4	9 0	1·984	2·292	106·79	151½	2·31	84·4	1·413	218·72	.. ..	.. ..	.. ..	.. ..
XVIII. Mixture of Iron from Warrington.	3	9 0	2·01	2·02	111·29	151½	2·875	90·5	1·964	287·65	1539	3·485	1484 from 1 sound bar.	3·270
XIX. Mixture of Iron, supposed to be Mr. Stirling's, called his 2nd quality	4	9 0	1·967	1·983	107·06	151½	2·39	86·	1·469	222·66	2736, result reduced for 2 inch square, from 4 experiments	2·72	2174, result reduced for 2 in. square, from 4 experiments.	2·382, result reduced for 2 inch square, from 4 experiments.

Remarks on some of the leading Results in the foregoing Abstract.

1st. The bars in Tables I., II., and III. were of the same sectional area, length, and weight nearly, but differed in the form of their transverse section. They were placed on supports at the same distance (13½ feet) asunder, and struck horizontally by the same ball, 303 lb. weight, suspended by a radius of 17 ft. 6 in. From the results given it appears that the beam, 3 in. square, and the rectangular beams, 6 × 1½ in. sections, struck on the broader and narrower sides respectively, had all very nearly the same strength to resist impact. The conclusions are drawn from a mean between two experiments in each case. In Table XV. six bars, each 2 × 1 inch section, and 5 ft. long, were laid on supports 4½ ft. asunder, and all struck by the same ball 75¼ lb. weight, with arcs of a radius 17 ft. 6 in. Three of them were struck on the broader and three on the narrower sides, and their mean chords of impact to produce fracture were 70 in. and 71·67 in. respectively, or nearly the same, agreeing with the results of the experiments upon the former bars.

2nd. In Table IV. the bars were of the same dimensions in section as those in Table I., or 3 in. square, but the distance between the supports was reduced one-half. The resulting breaking deflection, 1·23 in., was somewhat greater than one-fourth of that in Table I., or 4·375 in. and the vertical descent to produce fracture was nearly one-half, but rather more, the depth fallen through in the two cases being ·639 in. and 1·238 in. Comparing, in like manner, the half and whole bars in Tables V. and II., the depths are ·5521 in. and 1·2071 in. respectively. This result, coupled with the former one, shows that the depth fallen through to break the half bar is nearly half of that required to break the whole one. Comparing the results in Tables VIII. and XII., and also Tables X. and XIII., it appears also that a bar of half the length of another resists with nearly half the energy, but somewhat more.

3rd. The experiments in Tables I., II., III., IV., and V. afford illustrations of some of the conclusions in the large generalization of Dr. Young, deduced from neglecting the inertia of the beam. *(Nat. Phil., Lecture XIII.)* "The resilience of a prismatic beam, resisting a transverse impulse, follows a law very different from that which determines its strength, for it ■ simply proportional to the bulk or weight of the beam, whether it be shorter or longer, narrower or wider, shallower or deeper, solid or hollow. Thus, a beam 10 ft. long will support but half as great a pressure without breaking as a beam of the same breadth and depth which is only 5 ft. in length; but ■ will bear the impulse of a double weight striking against it with a given velocity, and will require that a given body should fall from a double height in order to break it."

4th. The experiments in Table VI. were made to compare the effects of striking a bar midway between the centre and one support with those of striking similar bars at the centre, as in Table IV. The great impacts, so near to the support in these cases, would necessarily cause it to yield slightly, and thus increase the resisting powers of the bars to sustain impact. In experiments made by the author several years ago, given in the Fifth Report of the British Association, page 112, on bars 1 in. square—some subjected to impacts in the middle, and others at half the distance between the middle and one support—the chord of impact necessary to produce fracture was nearly equal in the two cases. The ratio of the deflections, from equal impacts at the middle and at one-fourth span, was nearly constant under different increasing degrees of impact; the deflections at the middle from equal impacts being to those at one-fourth span, as 10 : 7 nearly. The relative ultimate deflections of the beam in the middle, and at a point half way between the middle and one end, ought to be as 10 : 7·5 nearly.

5th. The bars in Tables VIII., IX., and X. were all of the same iron and size, and the only difference was in the weights of the striking balls. The distances fallen through, and the work done by the balls to produce fracture, being respectively ·3159 and 190·498 with the 303 lb. ball; 1·2856 and 194·447 with the 151½ lb. ball; and 3·0506 and 230·32 with the 75¼ lb. ball, affording a good illustration of the resistance from the weight of the bar.

6th. The bars in Table XI. were of the same iron, Blaenavon No. 2, as the others, but re-melted, to ascertain the effect of melting this iron a second time without mixture upon its power to bear impact. The strength to resist blows was increased, but the iron was harder and much more unsound than before. The work done by the ball to break the beam in each case was increased in the ratio of 261 to 194.

7th. The deflections in cast-iron beams were always found to be greater than in proportion to the velocity of impact; whilst in wrought iron they were nearly constant with impacts of very different velocities. This fact shows that there is a falling off in the elasticity of cast iron through impact, analogous to that through pressure. The difficulty of obtaining a satisfactory theory of the power of cast-iron beams to sustain impact is considerably increased by this falling off in elasticity; but it is hoped that the varied nature of these experiments will tend much to reduce it.

Abstract No. IV.

ABSTRACT OF RESULTS ON VERTICAL IMPACTS UPON LOADED BEAMS OF CAST-IRON.

All of the beams were of the same weight and strength nearly. They were placed on supports at a constant distance asunder, and struck in the middle by the same ball, falling through different heights. The object of the experiments was to obtain the effect of additional loads, spread uniformly over the beam, in increasing its power of bearing impacts from the same ball. The beams were of Blaenavon Iron No. 2, cast to be 14 ft. 6 in. long and 3 inches square. The mean weight of beam, 410·7 lb.; mean weight of beam between supports, 382 lb. nearly; distance between supports, 13 ft. 6 in.; weight of ball, 303 lb.

Depth fallen through by Ball before Impact.	Velocity of Impact.	Deflections of Beam when loaded uniformly between the Supports, with Weights in addition to its own Weight, as below.							
		Weight of Beam . 376·765 lb. Unloaded, and without Load.	Weight of Beam . . 263·1 lb. Lead at centre 4	Weight of Beam . . 379·0 lb. Additional weight in centre . . 28	Weight of beam 387 lb. Additional Load 166 —— Sum of the two 553 Load at centre 4	Weight of Beam . . 386·8 lb. Additional Load . . 389·25 —— Sum . . . 776·05 Load at centre 4	Weight of Beam . . 387·2 lb. Additional Load . . 389·0 —— Sum . . . 776·2 No Load.	Weight of Beam . . 379·8 lb. Additional Load . . 391·2 —— Sum . . . 770·0 Load at centre 4	Weight of Beam . 382·08 lb. Additional Load . . 956·82 —— Sum . . 1338·9 Load at centre 4
Inches.	Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
9	6·945	1·99	..	..	..	..	..	1·698	..
12	8·0208	2·29	2·164	2·177	2·103	1·942	1·945	2·05	1·459
15	8·967	2·555	2·495	..	..	..	..	2·23	..
18	9·823	2·79	2·668	2·669	2·775 }	2·126	2·444	2·485	1·683
21	10·610	3·05	2·936	2·909	2·761 }	..	..	2·65	..
24	11·343	3·21	3·155	3·108	3·149	2·344	2·646	2·87	2·178
25½	11·692	3·33	..	..	..	..	..	..	..
27	12·031	3·40	3·406	3·418	3.371	..	..	3·064	..
30	12·683	Broke with 28½	3·495	3·638	3·688	3·168	3·169	3·319	2·454
31½	12·996	..	3·748	..	..	..	..	..	..
33	13·301	..	Broke.	3·804	3·614	..	..	3·36	..
36	13·893	..	..	3·978	4·049	3·344	3·427	3·569	2·696
39	14·460	..	..	4·164	4·168	..	..	3·665	..
42	15·006	..	..	Broke.	4·283	2·586 ?	3·766	3·82	2·966
45	15·532	..	..	..	4·485	..	..	3·925	..
48	16·042	..	..	..	Broke	Broke.	Broke.	4·129	3·176
54	17·014	..	..	..	..	..	..	4·24	3·386
60	17·934	..	..	..	..	..	..	4·516	Broke.
66	18·810	..	..	..	..	..	..	Broke. }	..

From the preceding table, we see that beams loaded in different degrees, bore more than beams unloaded, as below:—

Additional Load on Beam in lbs.	Height of Fall necessary to break the Beam.	Velocity of Impact answering to that Height.
None	28½ in.	12·632
Lead, 4lb. weight in centre	33	13·301
28 lb. in centre; no lead	42	15·005
166 lb. spread over beam + 4 lb. lead	48	16·042
389½ lb. spread over beam; 4 lb. lead	48	16·042
583 lb. spread over beam; no lead	48	16·042
391·2 lb. spread over; 4 lb. lead	56	18·310
956½ lb. spread over; 4 lb. lead	60	17·935

The set from the impact on these loaded beams was very great, but it did not appear to injure their strength more than in ordinary cases.

By comparing the impacts and deflections in the Abstract above, it will be seen that the deflections are nearly as the square root of the height fallen through by the ball, or as the velocity of impact.

Abstract No. V.—Synopsis of Experiments on the Extension and Compression of Cast-Iron.

1st. *The direct Longitudinal Extension of Bar Rounds, or Bars, 50 feet long and 1 inch Area of Section hearly, of four kinds of Cast-Iron, as mentioned below.*

Number of Table in which the Experiment is described.	Name of Iron.	Number of Experiments.	Mean Area of Section.	Weights, per Square Inch, laid on with their corresponding Extensions and Sets; the last, in each case, being the largest, where all were observed together. Weights.	Extensions.	Sets.	Mean Breaking Weight, per Square Inch of Section.	Mean Ultimate Extension.
			Inch.	lbs.	Inch.	Inch.		Inch.
I.	Low Moor Iron, No. 2	2	1·058	2117 6352 10586 14821	·09500 ·3115 ·5740 ·9147	·00345 ·0250 ·06425 ·12775	16408 lb. = 7·325 tons.	1·065 or [illegible] of the length.
II.	Blaenavon Iron, No. 2	2	1·0665	2096 6289 10482 13627	·09422 ·3085 ·5770 ·8370	·00263 ·01675 ·0575 ·11475	14675 lb. = 6·551 tons.	·9325 or [illegible] of the length.
III.	Gartsherrie Iron, No. 3	2	1·062	2109 6328 10547 14766 15820	·09225 ·3117 ·5962 ·9452 1·0497	·001 + ·01450 ·0475 ·11325 ·13912	16951 lb. = 7·567 tons.	1·167 or [illegible] of the length.
IV.	Mixture of Iron, composed of Leeswood, No. 3, and Glengarnock No. 3, in equal proportions.	3	1·063	2107 6322 10536 12648	·0914 ·2967 ·5349 ·6702	·00376 ·01823 ·04321 ·06417	14512 lb. = 6·6125 tons.	·6095 or [illegible] of the length.

In two of the bars the length, exclusive of the couplings, was 48 ft. 3 in. and the extensions and sets from them have been increased in the ratio of 50 to 48·25, to correspond to a length of 50 feet.

2nd. *The Extensions of Rods 10 feet long and 1 inch square, deduced from the preceding Experiments, and Compared with observed Compressions of Bars of the same Irons and the same size, cast with them for comparison, together with Formulæ for computing the Weights from the Extensions and Compressions.*

Extension, Table IX.

Number of Experiments.	Weights laid on, with the corresponding Extensions and Sets. Weights. (w.)	Extensions. (e.)	Sets.	$\frac{w}{e}$	Error in parts of the Weight, when it is computed from the Formula $w = 116117\,e - 201905\,e^2$
9	1053·77	·0090	..	117086	− [illegible]
9	1580·65	·0137	·00022	115131	− [illegible]
9	2107·54	·0186	·000545	113309	− [illegible]
9	3161·31	·0287	·00107	110150	+ [illegible]
9	4215·08	·0391	·00175	107803	+ [illegible]
9	5268·85	·0500	·00265	105377	+ [illegible]
9	6322·62	·0613	·00372	103142	+ [illegible]
9	7376·39	·0734	·00517	100496	+ [illegible]
9	8430·16	·0859	·00664	98139	+ [illegible]
9	9483·94	·0995	·00844	95316	+ [illegible]
9	10537·71	·1136	·01062	92762	+ [illegible]
9	11591·48	·1283	·01306	90347	− [illegible]
9	12645·25	·1448	·01609	87329	− [illegible]
6	13609·83	·1068	·02097	82133	+ [illegible]
4	14793·10	·1859	·02416	79576	− [illegible]

Compression, Table VI.

Number of Experiments.	Mean Weights laid on, with corresponding Mean Compressions, Sets, and Ratios of Weights to Compressions. Weights (w.)	Compressions (d.)	Sets.	$\frac{w}{d}$	Error in parts of the Weight, when it is computed from the Formula $w = 107703d - 363186\,d^2$.
8	2064·745	·01875	·00047	110120	− [illegible]
8	4129·49	·03878	·00226	106485	− [illegible]
8	6194·24	·05978	·00400	103617	+ [illegible]
8	8258·98	·07879	·00645	104823	+ [illegible]
8	10323·73	·09944	·00847	103819	+ [illegible]
8	12388·48	·12030	·010875	102980	+ [illegible]
8	14453·22	·14163	·01408	102049	+ [illegible]
8	16517·97	·16336	·01712	101102	+ [illegible]
8	18582·71	·18503	·02051	100430	+ [illegible]
8	20647·46	·20624	·02484	100114	− [illegible]
8	24776·95	·24961	·03220	99263	− [illegible]
8	28906·45	·29099	·04300	99331	− [illegible]
7	33030·80	·33941	·06096	97463	+ [illegible]
7	37159·66	·41149	·08421	..	..
..	..	..	..	..	..

Extension and Compression of Cast-Iron Bars.

The experiments to determine the effects of various weights, to extend and compress bars of cast-iron longitudinally, were made upon four different kinds of that metal. From the mean results given, in the preceding abstract, of Table IX. on the extension of bars, and Table VI. on their compression, the following formulæ were deduced for expressing the relations between the extensions and compressions of a bar 10 feet long and 1 inch square, and the weights producing them respectively:—

$$\text{Extension,} \quad w = 116117e - 201905e^2$$

$$\text{Compression,} \quad w = 107703d - 363186d^2,$$

Where w is the weight (in pounds) acting upon the bar, e the extension, and d the compression (in inches).

To express the relation between w and the corresponding extension and compression, when the length of the bar is reduced from 10 feet to 1 foot, we assume that the extension and compression are uniform throughout the length of the bar. Therefore the extension or compression of one-tenth its length will be reduced in the ratio 1 : 10. Consequently, in order that the value of w may remain unaltered in the formulæ, the co-efficients of e and d must be increased in the ratio of 10 : 1, and the co-efficients of e^2 and d^2 in the ratio of 10^2 : 1. These modifications being effected, the formulæ for a bar 1 foot long become

$$w = 1161170e - 20190500e^2 \text{ for extension,}$$
$$w = 1077630d - 3631800d^2 \text{ for compression.}$$

If the bars were 1 inch only in length, those to which the first formulæ applied would be reduced in length in the ratio of 1 : 120.

Consequently the extensions and compressions would be reduced in the same ratio; and in order that w might remain unaltered, the co-efficients of e and d must be increased in the ratio of 120 : 1, and the co-efficients of e^2 and d^2 in the ratio of 120^2 : 1. These changes being made, the formulæ for bars 1 inch long and 1 inch square become

$$w = 116117 \times 120e - 201905 \times 120^2 e^2$$
$$= 13934040e - 2907432000e^2 \text{ for extension,}$$
$$w = 107763 \times 120d - 36318 \times 120^2 d^2$$
$$= 12931560d - 522979200d^2 \text{ for compression,}$$

where, as before, w is expressed in pounds, d and e in inches.

Lastly, if the length of the bar be l inches, the corresponding formulæ for w may be deduced from those last given, by considering the bar to which those formulæ apply, increased in length in the ratio l : 1. Consequently as before, to adapt the formulæ to the present case the co-efficients of e and d must be diminished in the ratio 1 : l, and the co-efficients of e^2 and d^2 in the ratio of 1 : l^2.

The formulæ for a bar 1 inch square and l inches in length are, therefore,

$$w = 13934040\frac{e}{l} - 2907432000\frac{e^2}{l^2} \text{ for extension} \quad . \quad . \quad . \quad (A)$$

$$w = 12931560\frac{d}{l} - 522979200\frac{d^2}{l^2} \text{ for compression} \quad . \quad . \quad . \quad (B)$$

The mean tensile strength per square inch of section in the irons experimented upon was 15711 lb. = 7·014 tons, *and the mean ultimate extension for lengths of* 10 feet *was* ·1097 inch, *or* $\frac{1}{8}$ inch *nearly, being* [illegible] *part of the length.*

The mean compression of bars of the same metal and dimensions, by the weight 15711 lb. *(the breaking weight by extension, as above stated) was found from the experiments to be* 15488 inch, *or* [illegible] *part of the length.*

To find the values of (e) and (d) in terms of (w), in the preceding equations for Cast-Iron.

$$w = ae - be^2; \quad \text{whence } be^2 - ae = -w;$$

$$e^2 - \frac{a}{b}e = -\frac{w}{b}; \quad e^2 - \frac{a}{b}e + \frac{a^2}{4b^2} = \frac{a^2}{4b^2} - \frac{w}{b};$$

$$\therefore e = \frac{a}{2b} \mp \sqrt{\frac{a^2}{4b^2} - \frac{w}{b}} \quad . \quad . \quad . \quad . \quad (C)$$

Extension of a bar l inches long and 1 inch square in terms of the weight stretching it:—

From equation (A) for elongation of bars of cast-iron, we have, in equation (C),

$$a = \frac{13934040}{l}, \quad b = \frac{2907432000}{l^2},$$

substituting these values of a and b in (C), we have,

$$e = \frac{13934040}{5814864000} \times l \mp \sqrt{\left(\frac{13934040}{5814864000}\right)^2 l^2 - \frac{wl^2}{2907432000}}$$

$$= \cdot 00239628l \mp \sqrt{\cdot 0000057421 5 l^2 - \cdot 000000000343946 l^2 w}$$

$$\therefore e = l\left\{\cdot 00239628 - \sqrt{\cdot 0000057421 5 - \cdot 000000000343946 w}\right\}, \text{ (D),}$$

where w is in lbs. and e in parts of an inch, the negative sign being that alone which is applicable in the quantity under the root.

If $l =$ 1, the extension is that produced by a length of bar = 1 in.
If $l =$ 12, „ „ „ = 1 ft.
If $l =$ 120, „ „ „ = 10 ft.

Example 1. Suppose $w = 11591 \cdot 48$, and $l =$ 10 feet or 120 inches, then substituting for w and l their values in equation (D), we have

$$e = l\left\{\cdot 00239628 - \sqrt{\cdot 00000574215 - \cdot 00000398684}\right\}$$

$$= l\left\{\cdot 00239628 - \cdot 00132488\right\} = 120 \times \cdot 0010714 = \cdot 128568 \text{ inch.}$$

* Comparing this with the result in Table IX., on extension of bars, from the same pressure 15491·48 lb., we have a defect of [illegible]th, the real extension being ·1263 inch.

Example 2. Suppose $w = 2107 \cdot 54$ lb. and $l =$ 10 feet; substituting for w and l in equation (D) we have

$$e = l\left\{\cdot 00239628 - \sqrt{\cdot 00000574215 - \cdot 00000072488}\right\}$$

$$= l(\cdot 00239628 - \cdot 00223993) = 120 \times \cdot 00015635 = \cdot 01876$$

It should be ·0186, ∴ error = [illegible].

Compression of a bar l inches long and 1 in. square in terms of the weight producing it:—

The relation between the weight and the compression being expressed by an equation of a similar form to that between the weight and the extension, or $w = ad - bd^2$, we obtain in the same manner as before,—

$$d = \frac{a}{2b} \mp \sqrt{\frac{a^2}{4b^2} - \frac{w}{b}}$$

substituting the values of a and b derived from the equation (B) for cast-iron, or $\frac{12931560}{l}$ for a, and $\frac{522979200}{l^2}$ for b, we obtain—

$$d = \frac{12931560}{1045958400} \times l \mp \sqrt{\left(\frac{12931560}{1045958400}\right)^2 l^2 - \frac{wl^2}{522179200}}$$

$$= l\left\{\cdot 012363359 - \sqrt{\cdot 000152853 - \cdot 00000000191212 w}\right\}. \quad . \text{(E)}$$

Where w is in pounds and d in inches, the quantity under the root is affected by the negative sign, which alone is applicable in this instance.

Example 1. If $w = 8258 \cdot 98$ lb., and the length 10 feet = 120 inches, we obtain by substituting the value of w and l in equation (E),—

$$d = l\left\{\cdot 012363359 - \sqrt{\cdot 000152853 - \cdot 00001579216}\right\}$$

$$= (\cdot 012363359 - \cdot 0117073)\, l = \cdot 07872 \text{ inch.}$$

Comparing this with the experimental result for this pressure in Table VI. on compression of bars, or ·07878, we find the deviation or error equal [illegible] of the latter.

Example 2. If $w = 6194 \cdot 24$ lb. and $l =$ 120 inches as before,

$$d = l\left\{\cdot 012363359 - \sqrt{\cdot 000152853 - \cdot 000118441}\right\}$$

$$= l(\cdot 0004890) = \cdot 05868 \text{ inch. It should be } \cdot 05978 \ \therefore \text{ error} = \text{[illegible]th.}$$

The first example is the case of least deviation of the formula from the results of experiments in Table VI.; and the second is that of greatest deviation for pressures between 2 and 14 tons per square inch, the range between which the results are most trustworthy.

Example 3. If $w =$ 15711 lb.—the weight which would tear asunder an inch bar of these irons—to find the compression of a bar 10 feet long and 1 inch square from the same weight.

Substituting in equation (E) the values of w and l,

$$d = l\left\{\cdot 012363359 - \sqrt{\cdot 000152853 - \cdot 00000000191212 w}\right\}$$

$$= l(\cdot 012363359 - \cdot 0110820) = l(\cdot 0012813) = \cdot 15376 \text{ inch.}$$

The decrement, as obtained from the results of experiment in Table VI., on compression of bars, was ·15488 inch.

Extension.

(Computed from the Formula obtained.)

Weight.	Computed Extension.	Real Extension.	Error in parts of Real Extension.
1053·77	·00922	·0090	+ [illegible]
2107·54	·01876	·0186	+ [illegible]
4215·08	·03893	·0391	− [illegible]
6322·62	·06090	·0613	− [illegible]
8430·16	·08523	·0859	− [illegible]
10537·71	·11293	·1136	− [illegible]
12645·25	·14503	·1448	+ [illegible]
14793·10	·19051	·1859	+ [illegible]

Compression.

Weight.	Computed Decrement.	Real Decrement.	Error in parts of Real Decrement.
2064·745	·01926	·01875	+ [illegible]
6194·24	·05863	·05978	− [illegible]
10323·73	·09909	·09944	− [illegible]
14453·22	·14077	·14153	− [illegible]
18582·71	·18379	·18505	− [illegible]
24776·95	·25114	·24961	+ [illegible]
33030·80	·34705	·35341	− [illegible]

Transverse Flexure.

When a beam is bent in any degree the fibres or particles on the convex side are extended, and those on the concave side are compressed; and there is a line within the beam, intermediate between the two sides, in any transverse section where the particles are neither extended nor compressed. This is called the neutral line, and the particles on each side of it are stretched or compressed according to their distance from it; but the *force* exerted by these particles is not in proportion to the distance, in cast iron, at least, which we are treating of. It varies as a function composed of the first and second powers of the distance nearly.

Thus, in the longitudinal extensions and compressions of a bar one inch area of section and l inches long, we have from the mean results of experiments on four kinds of cast-iron, equations (A) and (B),

$$w = 13934040\,\frac{e}{l} - 2907432000\,\frac{e^2}{l^2},$$

$$w = 12931560\,\frac{d}{l} - 522979200\,\frac{d^2}{l^2},$$

where w is the weight in pounds producing the extension e or compression d in inches.

To apply this to transverse pressure, suppose the extension e and compression d of a small length of the material at a distance l from the neutral line to be represented by $ml, m'l$, respectively, then the extension and compression at any other distance x of a portion of the material originally of the same length will be mx and $m'x$, and the formulæ will become—

$$w' = 13934040\,\frac{mx}{l} - 2907432000\,\frac{(mx)^2}{l^2} \quad . \;.\; . \quad (F)$$

$$w'' = 12931560\,\frac{m'x}{l} - 522979200\,\frac{(m'x)^2}{l^2} \quad . \;.\; . \quad (G)$$

where w', w'', are the forces of tension and compression exerted by the fibres at a distance x from the neutral line, and m, m' co-efficients dependent on them.

In the 'Experimental Researches on the Strength of Iron, published by the author, and forming an additional volume to 'Tredgold on Cast-Iron,' an attempt was made to give a more general computation of the strength of beams than had hitherto been done, the solution depending upon the supposition that the resistance of the particles to tension and compression varied in terms of the 1st and some other constant power of the extension and compression. Thus if x be the distance from the neutral line—

$$\phi(x) = x - \frac{x^v}{na} = x - \frac{x^2}{na},\ \text{if } v = 2 \quad . \;.\; . \;.\; \quad (J)$$

$$\phi'(x') = x' - \frac{x'^{v'}}{n'a} = x' - \frac{x'^2}{n'a},\ \text{if } v' = 2 \quad . \;.\; . \quad (K),$$

where $\phi(x)$ and $\phi'(x')$ would be quantities respectively proportional to the forces of extension and compression of a particle at a distance x from the neutral line, and n, n', quantities supposed to be constant.

From the experiments given in this inquiry, it appears that v, v', are equal to 2; and in the equations (J) and (K) a is the same quantity as l in equations (F) and (G), $a = l$; and to adapt the formulæ (F), (G), for cast-iron, found before, to the forms above, we have—

$$\frac{w'l}{13934040\,m} = x - \frac{2907432000\,m^2l}{13934040\,ml^2} \times x^2$$

$$= x - \frac{2907432000\,m}{13934040} \times \frac{x^2}{l},\ \text{for extension} \quad . \;.\; . \;.\; \quad (L)$$

In like manner—

$$\frac{w''l}{12931560\,m'} = x - \frac{522979200\,m'}{12931560} \times \frac{x^2}{l},\ \text{for compression} \quad . \quad (M)$$

Whence we obtain the values of n, n', in equations (J), (K), as below,—

$$n = \frac{13934040}{2907432000\,m},\quad n' = \frac{12931560}{522979200\,m'}$$

By inserting these values in the formulæ given in the work above referred to, the position of the neutral line and the strength of a cast-iron beam of the form considered may be found.

Abstract No. VI.

ABSTRACT *of Results on the Transverse Strength of Cast-Iron Bars of different sizes, but mathematically similar, or relatively proportional in all their dimensions.*

The bars were of Blaenavon iron, No. 2, and were respectively cast to be 3, 2, and 1 inches square, and 15, 10, and 5 feet long. They were placed on supports 13½, 9, and 4½ feet asunder, and the strength and ultimate deflections of the bars, when reduced to their exact size, were as below:—

Size of Bars.		Vertical Pressures.				Horizontal Pressures computed from the Vertical Pressures.			
		Strength.		Ultimate Deflection.		Strength.		Ultimate Deflection.	
Ft. span.	In. sq.	lbs.	Mean	Inches.	Mean.	lbs.	Mean.	Inches.	Mean.
4½	1	461 437 423	440	1·796 1·850 1·6917	1·779	468 444 430	447	1·823 1·880 1·720	1·806
9	2	1249 1414 1121 1097 1552*a* 1591*b*	1336	2·996 3·486 2.327 2·498 3·620 2.984	3·0035	1303 1469 1175 1151 1616 1648	1394	3·032 3·622 2·649 2·621 3·746 3·085	3·125
13½	3	2698 2671 3389*c* 2686*d*	2861	4·863 4·3908 5·024 4·391	4·667	2877 2854 3373 2869	3043	5·186 4·692 5·297 4·690	4·966
6¾	3	6341 5795 6215	6117	1·3319 1·190 1·353	1·2916	6431 5885 6306	6207	1·351 1·208 1·373	1·311

The results marked with the letters *a*, *b*, *c*, *d*, are from the bars which had been previously subjected to 4000 impacts, each bending them through ⅓rd of their ultimate deflections.

The strengths of similar bars 1, 2, 3 inches square, and 4½, 9, and 13½ feet between the supports are respectively 447, 1394, and 3043 lb. to resist an horizontal pressure.

If the elasticity of the beams had been perfect, their strengths should have been as the square of their lineal dimensions, or as 1, 4, 9. Dividing, therefore, the strengths as above by these squares, the quotients ought, on this supposition to be equal. We have, however,

$$\text{From the smallest bars} \quad . \;.\; \quad \frac{447}{1} = 447,$$

$$\text{From the next larger bars} \quad . \quad \frac{1394}{4} = 349,$$

$$\text{From the largest bars} \;.\; . \;.\; \quad \frac{3043}{9} = 338.$$

The quotients are unequal; but we see that the deviation from theory, on the supposition of perfect elasticity, is much greater in the smaller than in the larger bars, and that the strength of the smallest bar is greatly above that derived from others, partly, it is probable, arising from defect of elasticity, but principally from the superior hardness of the smaller castings.

The ultimate deflections of similar elastic bars from horizontal pressure are as the lineal dimensions of the bars, nearly; and, therefore, similar bars, one, two, and three inches square, ought to deflect before fracture in those proportions. The ultimate deflections from experiments, as above, are below.

In bars, 1 inch square	. . . .	1·806
„ 2 inches square	. . .	3·196
„ 3 „	. . . .	4·966

The deviation in the ultimate deflection of the bars, from 1, 2, 3, the ratio of their size, is, therefore, larger in the smallest (hardest) bars than in the others.

In Tables V. and IX., on the transverse strength of bars, of wrought and cast-iron mixed, we find a similar falling off to that above, in the strength of the larger bars below that of the smaller ones, as is shown in the following extracts:—

Size of Bar. Ft. Span.	In. sq.	Strength to bear Horizontal Pressure. lb.	Ultimate Deflection from Horizontal Pressure.
9	2	2230 from 4 experiments on 1st sample	2·720 in.
		1545 from 2 experiments on 2nd sample	2·258
4½	1	630 from 4 experiments on 1st sample	1·4995
		505 from 4 experiments on 2nd sample	1·320

General Remarks on the Rapidity of Increase of Transverse Strength of Square Bars for Small Increments of their Sectional Dimensions.

The rapidity with which the transverse strength of square bars increases for small increments of their sectional dimensions does not appear to have been always adequately considered in experimental inquiries. *For square bars of constant length between the supports, the transverse strength varies as the cube of the side of the square,* consequently, for bars not greatly exceeding 1 inch square,—such as have most frequently been subjected to series of experiments,—an error of 1/10th of an inch (for example) in the sectional dimensions, will produce an error of nearly ⅓rd in estimating the transverse strength. It is, however, by no means unusual to assume bars, cast to be 1 inch square, to have exactly their nominal dimension; variations of the actual dimensions, sometimes approaching to, or even exceeding 1/10th of an inch, being neglected.

This source of error has been avoided in the present series of experiments,—and in nearly all others by the author,—by measuring the transverse dimensions of each bar to thousands of an inch, and reducing the results by theory to those for the intended size of the casting. The nature and extent of the error will be easily seen by the following table, in which is exhibited the difference of strength of square bars, of which the transverse dimension increases by hundredths of an inch. The breaking weight of the bar 1 inch square is taken at 448lb. (from the mean of experiments on cast iron). It will be observed from this table, that an error of less than 1/25th of an inch in the measure of the side of the square bar produces an error of ⅛th of the strength. A similar error of 1/10th of an inch produces an error of ⅓rd the strength, and an error of less than ⅐th of an inch produces an error of ½ the strength.

Comparative Transverse Strength of Bars of Sections slightly differing from 1 square inch.

Side of Square of Bar.	Cube of Side.	Strength, or Breaking Weight.	Approximate Error from assuming the Bar as 1 inch Square.
1·00	1·000	448	..
1·01	1·0303	462	1/33
1·02	1·0612	475	1/16
1·03	1·0927	489	1/11
1·04	1·249	504	⅛
1·05	1·1576	519	⅙
1·06	1·1910	534	⅕
1·07	1·2250	549	2/9
1·08	1·2597	564	¼
1·09	1·2950	580	3/10
1·10	1·3310	596	⅓
1·11	1·3676	613	4/11
1·12	1·4049	629	⅖
1·13	1·4429	646	4/9
1·14	1·4815	664	½
1·15	1·5209	681	10/19

NEW WESTMINSTER BRIDGE.

Sir—Several designs have been given in for building a new bridge across the river Thames at Westminster. The designs have been lithographed, and are to be found in the "Third Report, Westminster Bridge and New Palace, ordered by the House of Commons to be printed 6th August, 1846."

The design proposed by Mr. Walker, for a stone bridge, consists of five arches, segments of circles, and the information regarding those arches, as stated in the design, is as follows:—

> "Span of centre arch, 150 feet.
> Span of side arches, 140 and 120 feet.
> Soffit of centre arch above Trinity standard, 24 feet."

The versed sine or heights of those five arches above the springing line have not been figured in on the design, nor the radius of any of the arches. The figured dimensions of the piers are omitted, and also the radius of the curve which the soffits of the five arches should tangent; but by measuring on the design, the versed sines or heights of the first and last arches between the springing line and their soffits have been found to be each 15 feet, and the centre arch about 20 feet. The thickness of the piers, measured on the plan, 18, 20, 20, and 18 feet, making a total of 76 feet. The distance across the river, between the abutments, 746 feet, and the clear waterway 670 feet. The horizontal distance, or length of the chord line between the versed sines of the first and last arches, is 626 feet.

The spans of the arches of 150, 140, and 120 feet, have all different radii. Have they been put into the design at random? or have they been the result of calculation emanating from some rule of science? Has this been the reason of the engineer having omitted to figure in the versed sines of the five arches on the plan?

A design for an iron bridge is also given by Mr. Walker, with a short note, as follows:—

> "Span of centre arch, 150 feet.
> Span of side arches, 140 and 130 feet.
> Soffit of centre arch above Trinity standard, 24 feet."

This makes a clear waterway of 690 feet, whereas Mr. Walker's design for a stone bridge gives only a waterway of 670 feet, being a difference of 20 feet of waterway between the two designs. This is the very limited and variable information contained in Mr. Walker's two designs for a bridge over the Thames at Westminster.

Mr. George Rennie has given in a design for a stone bridge, consisting of seven elliptic arches; the spans of the arches and their heights have been figured in on the design. The waterway of the seven elliptic arches is 760 feet, and the width between the abutments, 832 feet, which varies greatly from the dimensions given by Mr. Walker.

	Waterway.	Width between Abutments.
Mr. Rennie's bridge of seven arches	760	832
Mr. Walker's stone bridge, five arches	670	746
Difference	90	86
Mr. Rennie's bridge of seven arches	760	832
Mr. Walker's iron bridge, five arches	690	756
Difference	70	76
Mr. Walker's iron bridge, five arches	690	756
Mr. Walker's stone bridge, five arches	670	746
Difference	20	10

Mr. Barry's iron bridge of five arches has a waterway of about 720 feet, but no figured dimensions have been given.

As your *Journal* is read by many intelligent persons well acquainted with calculations and the properties of the circle, perhaps some of them would be kindly pleased to give the solution of the following problem, and the formulæ on which the solution and calculations have been based.

Elements given.

	Feet.
Distance between the abutments, C, C	746
Ordinates between A, a′	14
Ordinates between A, a′	20
Ordinates between A, a′	15
Horizontal distance between the ordinates	612
The width of each of the five segment arches by calculation, all of the same radii, to span a waterway of	670
Four piers, two on each side of the centre arch to be 20 feet thick each, and two at the side arches 18 feet thick each; the breadth or thickness of the whole four piers	76

b, b, b, b, line, from which the arches are to spring.

a′, a′, a′, three points through which a curve line shall pass, and tangent the soffits of the five segment arches.

Required from the above Elements.

1. To determine the radius of the curve which shall pass through the three points a', a', a', and which shall tangent the soffits of the five segment arches.

2. To determine by calculation the span of each of the five segment arches, which shall, when added together, give a waterway of 670 feet in width; and, with the thickness of the four piers, 76 feet broad, a space of 746 feet in width between the abutments or points C, C.

3. To determine by calculation the versed sines of each of the five arches.

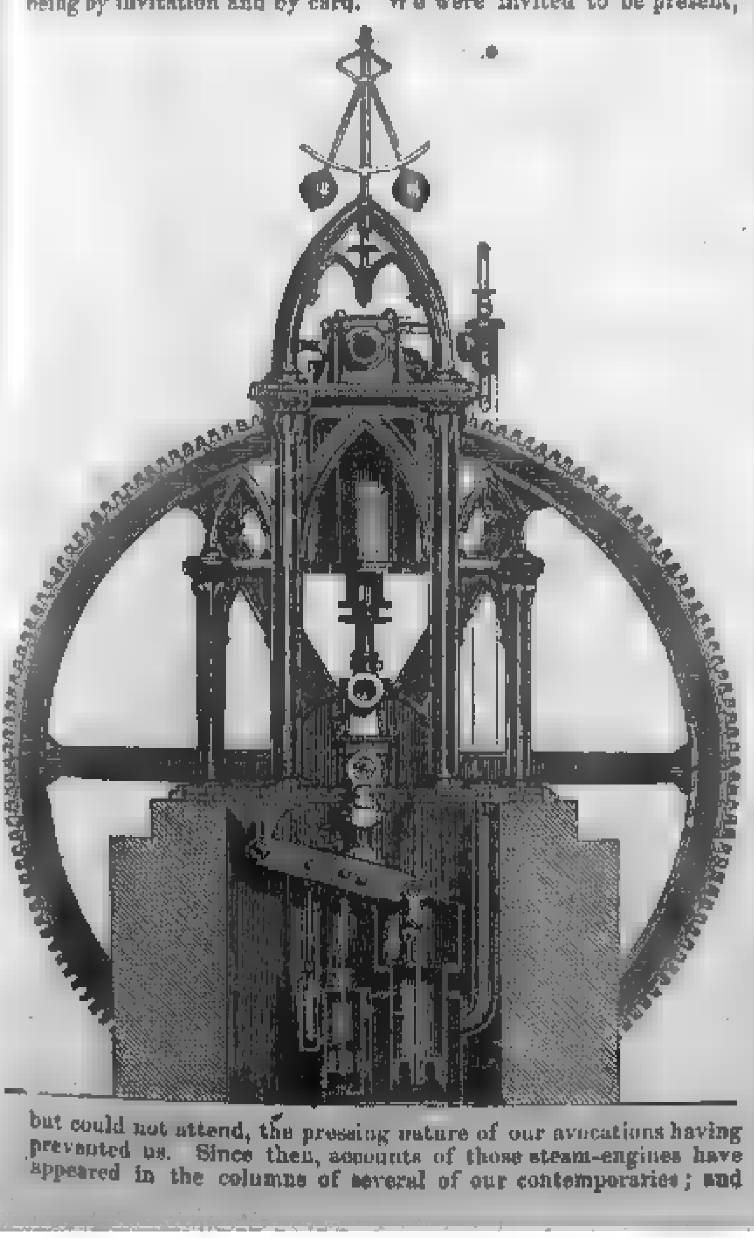
4. The soffits of the five segment arches to tangent the curve line which shall pass through the three points a', a', a'.

5. The length of the radius which shall be common to the five segment arches contained between the springing line b, b, b, b, and the curve line passing through the three points a', a', a'.

February, 1850. B.

THE SMYRNA STEAM FLOUR-MILLS AND THE WATT AND WOOLF STEAM-ENGINES.

On Saturday, the 19th of January last, a private view of two powerful steam-engines, on the Woolf principle, but with oscillating cylinders, took place at the works of the Messrs. Joyce, engineers, Greenwich; we would rather say, a public view, the admittance being by invitation and by card. We were invited to be present,



but could not attend, the pressing nature of our avocations having prevented us. Since then, accounts of those steam-engines have appeared in the columns of several of our contemporaries; and from one of them, the *Mining Journal*, we shall take leave to extract the following:—

"The engines which the Messrs. Joyce have constructed for this purpose, have been formed upon a principle entirely new in this country, which has been found to work with unexampled advantage in several establishments in which the same kind of engines has been adopted. In their general arrangement, they may be described as belonging to the class of steam-engines termed "oscillating," from the circumstance of their cylinders vibrating on axes or trunnions, in order that the piston-rods may constantly act upon the cranks without the intervention of what in stationary engines is termed a parallel motion, a contrivance, by which the vertical motion of the piston-rod is adapted to the circular motion of the cranks. The principle discovered by Woolf, of introducing steam of a high-pressure into a small cylinder, and allowing it to act expansively in a larger one at a pressure smaller than the original, in the proportion of the circular sections of the cylinders, and afterwards to add to its effective force by condensation, is here applied in an extremely ingenious manner, and with a simplicity of arrangement having reference to the multiplicity of objects which are to be provided for simultaneously in the machine. But what Woolf did by the intervention of parts which rendered the action indirect, is here done without the aid of subsidiary arrangements, and the action is direct. The oscillating cylinders are for this purpose inverted, and vibrate upon steam-ways at their upper extremities. The long horizontal shaft upon which the piston-rods act, is furnished with cranks, so that the dead point is always got over, and the motion transmitted by cogged-wheel gearing, the large wheel being 16 feet in diameter—the fourteen mills, each of which is furnished with a pair of millstones, grinding in the usual way.

A report from Mr. Elijah Galloway, C.E., who was employed by Mr. T. Comer, to examine the machinery for him, is now before us, from which we gather, that the capacity and dimensions of the engines and machinery are in all respects, more than ample both for power and strength—the engines, moreover, being equal to nearly double the power required. With reference to the four boilers employed to generate the requisite quantity of steam, Mr. Galloway expresses his conviction that *one* alone will be nearly capable of supplying both engines, thus affording the command of full three times the power required, and which would, in his opinion, work safely at "double the proposed maximum pressure." The report concludes with expressing the great satisfaction on his part of the economy attendant on the application of the machinery, and the nicety and perfection with which it has been constructed.

In the course of conversation we were given to understand that an engine of 12-horse power, at the Greenwich Iron Works, upon the principle referred to, costs only 30s. per week for 12 hours per day, while several establishments at home and abroad, prove the consumption of fuel to be less than 3 lb. per horse power per hour."

Similar accounts to the preceding have appeared in the other publications to which we have had occasion to allude. Those accounts are of so extraordinary a nature, and so apt to impress the public mind, either with error or doubt—error with those who do not thoroughly comprehend the construction and principles of the steam-engine, and doubt with those who do—that we feel ourselves impelled, by a sense of public duty, to make some comments.

This course appears to us to be the more incumbent—the more imperative, as it shadows forth a matter of considerable interest at this present time—the comparative value of the Watt and the Woolf steam-engines.

In the cotton-spinning districts of Glasgow and Manchester, many Woolf-engines have been erected recently; and others, by the addition of another cylinder, and by working the steam at high pressure in the new cylinder, and expanding it in the old, have been changed into Woolf-engines.

These introductions and adaptations have taken place since the Woolf-engine has been re-patented by Mr. MacNaught, of Glasgow; and, as we have received letters from several gentlemen, interested in cotton-spinning, claiming our particular attention to the matter, which is of importance to them, we shall now enter upon the subject.

In the foregoing accounts it is stated, that the Messrs. Joyce, the engineers of Greenwich, have made a pair of magnificent and powerful steam-engines, with all the appurtenances of a flour-mill, to work fourteen pair of stones; that "the engines *are on the double-cylinder expansive plan*, originally patented by Woolf;" that "the Messrs. Joyce have succeeded in giving a *direct* action to that which Woolf and his followers gave *indirectly*, by which, amongst other beneficial results, the consumption of fuel *is less than 3 lb. per horse power*, it being about 12 lb. under the old system;" *and that "these results have been mainly achieved by the introduction of a system of inverted and oscillating cylinders*, which cause the force of the piston-rods to act directly upon the crank-pin, without the interposition of any intermediate machinery, so that the friction of

the whole engine is reduced to its minimum, *while its simplicity proportionably reduces the chances of accident.*"

Now, Woolf, to the best of our recollection, patented his double-cylinder expansive steam-engine in 1804; and, in conjunction with his partner, Mr. Edwards, erected one at the saw-mills at Lambeth; afterwards and now in the possession of Mr. Smart, where we saw it working in 1825. He erected one also, we think, at the brewhouse of Messrs. Meux and Co., where he gave a public challenge to Messrs. Boulton and Watt, which excited much attention. Mr. Woolf shortly afterwards went into Cornwall, and erected some at the mines there, the duties of which, by the consumption of each bushel of coal, were so unprecedentedly great, that the attention of the mining interests of that county was publicly engrossed by it. But more of this anon.

Steam-engines, on the double-cylinder expansive principle of Woolf, were afterwards erected in the neighbourhood of London, by Messrs. Pullen and Wentworth, of Wandsworth; particularly for flour-mills on the river Wandle. We had occasion in 1830, to make a professional survey of the power and effect of the mills on that stream—both those impelled by steam and those impelled by water. We then saw several of the steam-engines that had been so erected; also others at the engine-yard of Messrs. Pullen and Wentworth; also one at a flour-mill at Bermondsey. We state these things to show, that although steam-engines on this principle have been long well-known, they have not met with the general recognition and sanction of our best engineers.

It was the latter part of 1814 that Woolf's engine, with the double cylinder, was introduced into Cornwall. The large cylinder was 45 inches diameter. It was erected at the mine called "Wheal Abraham." Its duty, as first reported, in October of that year, was 34 million pounds lifted 1 foot high, by the consumption of each bushel of coal, weighing 94 lb. It was discovered soon afterwards that there was a defect in some of the castings which being removed, the duty advanced in the following year, to upwards of 52 millions. A second engine, with a 53-inch cylinder, was erected next year by Woolf, at Wheal Var. Its duty was 50 millions. These duties, which were tested and verified, produced much excitement, as well they might, amongst the mining interests of Cornwall; for at that time the number of other engines reported at the mines was 35, and the average duty was 20½ millions.

In 1816, Messrs. Jeffree and Gribble erected a new engine *with single cylinder* at Dolcoath, 76 inches diameter. Its duty amounted to 40 millions. Sims also erected one at Wheal Chance, which attained to 46 millions. Woolf, in 1820, erected *a single-cylinder* engine at the Consolidated Mines, 90 inches diameter and 10 feet stroke; its duty in December of that year reached 38¼ millions. At this period, "*Woolf's engines with double cylinders, owing to the difficulty of keeping them perfect, had fallen to the average of the best single-cylinder engines; and after this period began to be disused in the mines.*"*

In 1825, Sims erected *a single-cylinder* engine at Polgooth, which performed 54 millions; in 1827, Captain William Grose erected one at Wheal Towan, the duty of which was 62 millions; and in October of that year, Woolf's 90-inch *single cylinder*, at the Consolidated Mines, reached the hitherto unprecedented duty of 67 millions. These duties were shortly afterwards surpassed by Grose's engine, at the Wheal Towan, in 1828, reaching 87 millions; and that of Mr. William West, at the Fowey Consols and Lanescot Mines, attaining to 125 millions, which is the highest amount of duty yet recorded.

We state these things to show, that although the mining interests of Cornwall gratefully acknowledged themselves indebted to Woolf for first pointing out to the engineers of that important district, the advantages of using high-pressure steam worked very expansively, and which led them to adopt their present simple and effectual mode of using and expanding the steam in one cylinder only; yet they have found it necessary, entirely to supersede his more complicated and costly machines, the double-cylinder engines.

Thus far examined, therefore, we cannot perceive what advantage the Messrs. Joyce propose to themselves by the adoption of the *double-cylinder* Woolf-engine. Most engineers, we believe, thoroughly conversant with the constituencies of steam and the action of the steam-engine, are aware that the only advantage Woolf conceived he could gain by using the double-cylinder engine was, that of working the steam expansively. The idea of employing steam *expansively*, originated with the great James Watt; and for its use or application he obtained letters patent. He proposed to employ the principle in a *single-cylinder* engine; Woolf in an engine with *two cylinders*. The timidity of James Watt deterred him from employing steam of very high pressure, or at from 40 to 60, or to 80 lb. on the square inch beyond the atmosphere. Woolf, having no fears of the kind, had recourse to it; and as the expansive force of steam, for practical purposes, becomes more tangibly apparent at high degrees of pressure than at low, Woolf derived the advantage. In no other respect was any superiority in the Woolf-engine made manifest. The shrewd, practical, mining engineers of Cornwall soon discovered this; and, in their practice, abandoned the complicated double-cylinder engine of Woolf, for the single cylinder of James Watt. For it may be averred, that the *single-cylinder* steam-engine now used in Cornwall, although better proportioned in some of its parts and larger in dimensions—although the steam employed is of much higher pressure, and more attention is paid to the preservation of it by non-conducting substances, —is truly, *and unquestionably*, the simple *single-cylinder steam-engine* of the great James Watt.

We therefore repeat, we cannot perceive what advantage the Messrs. Joyce propose to themselves, by adopting a principle which has been tried, and "*found wanting;*" in other words, by having recourse to the complex apparatus of Woolf, when the simple arrangement by Watt is found to be equally as efficient.

It may, perhaps, be urged, that although expanding steam in a single-cylinder engine may answer very well for pumping, where the motion at both ends of the stroke is intermittent; yet it will not answer so well in rotatory fly-wheel engines where the motion is continuous, and intended to be equable. But here we must be permitted to dissent from any such opinion. The expansive system is now very commonly adopted to rotatory fly-wheel engines by our best engineers; and we ourselves were principally instrumental to its first adaptation to the delicate processes of the cotton manufacture, where some of the spindles make from seven to eight thousand revolutions in a minute, and where the least variation of speed would produce a very perceptibly injurious effect. If the expansive system can be used under such circumstances, surely it may be similarly employed to a flour-mill, which does not need such precise equability of motion, and where the stones that grind the flour do not revolve generally at a greater speed than from 120 to 140 revolutions per minute? We repeat, therefore, we cannot perceive what advantage the Messrs. Joyce propose to themselves by adopting a complex apparatus instead of the simple one.

In the same paper it is stated, that the Messrs. Joyce derive much important advantage *by the adoption of vibrating or oscillating cylinders*, which require no beam, and by which the power is communicated direct from the steam-piston to the crank.

This also was a discovery of the great James Watt, who took out a patent for its application. For some cause or other, it remained dormant a great many years. In or about the year 1828, the principle was carried into successful practical operation by that highly eminent firm, Messrs. Maudslay, Son, and Field, in consequence of Mr. Joseph Maudslay having invented, and taken out letters patent for, a method of applying the long D slide to the vibrating cylinder. This was the *first* application of the oscillating cylinder to the steamboat, which has since become so general in boats intended for river navigation. We were present at the first experimental trip, having been invited by that able engineer and splendid mechanician, the late Henry Maudslay, Esq. There were present, besides the late Mr. Maudslay and his son, the inventor, Mr. Joshua Field, Mr. Bryan Donkin, the late Sir Isambert Marc Brunel, and others, whose names confer weight, honour, and dignity to the profession. The experimental trip was from London to Richmond, and back again. It took place at a time when there was a heavy flood of water in the Thames. The boat was of light draft, the engines were powerful, and it answered admirably well.

That the oscillating principle is well adapted to boats of light draft, there cannot, we think, be a difference of opinion. But we must be pardoned, if we doubt its equal applicability to stationary purposes. At any rate, we cannot perceive how it is that so great an advantage has been obtained by the adoption of this principle of construction, added to that of the double cylinder of Woolf, as is now stated to be; and by which it is affirmed, that the quantity of coal consumed for each horse power per hour, is less than three pounds.

We cannot give credence to this statement; nor can we believe that it has been given to the public with the sanction of so respectable a firm as the Messrs. Joyce. We cannot perceive in what respect these engines can consume less coal, per horse power, than other kinds of engines, with beams or without beams, equally well

* "Historical Statement of the Improvements made in the Duty performed by the Steam-Engines in Cornwall." By Thomas Lean and Brother, Registrars and Reporters of the Duty of Steam-Engines. London: Simpkin and Marshall. 1839.

constructed. If we be in error, we shall be glad to be set right; and shall he rejoiced to be become acquainted with the minutiæ of so important and so gratifying a fact, that a rotatory fly-wheel engine, for land purposes, can be made to do with *three pounds of coal* per each horse power per hour.

We still doubt the fact: if we be in error, we respectfully invite the Messrs. Joyce to verify the statement, by making known to the public, through our *Journal*, the following particulars to guide them:—

Diameter of each steam-cylinder, and length of stroke?

At what pressure the steam was worked in the small cylinder?

The number of strokes made per minute?

The diameter and weight of the mill-stones; and the number of revolutions made by them per minute?

The quantity of wheat ground per hour, when the bolting and dressing machines were at work as well?

The nominal power of the engines?

And the quantity of coal consumed?

We shall be glad also to learn, whether the consumption of coal per each horse power, per hour, were estimated on the full indicated power—inclusive of friction, the power consumed by the pumps, &c.; or whether it were given to the world on the nominal horse power, as it ought to have been? If on the former, its tendency is, most unquestionably, to convey an erroneous impression.

We shall be glad to hear from the Messrs. Joyce on this subject.

THE HEALTH QUESTION—WATER SUPPLY ADMINISTRATION.

Although there have been successive agitations for better water, each of which has died away, yet the time now comes when the public is in earnest, and something will be done, so that the question only remains how. Undoubtedly it is of much importance, that the best spring should be gone to; but it is of much more moment, that the best mode of management should be resorted to. When we say "the best," we do not mean the best theoretically, but that which will work most energetically, and in which the public will have most confidence. This, too, is a matter which as much interests our readers as the levels and pressures incident to the water supply. Indeed, what can interest them more than to know who are to be their employers? Further, it must not be lost sight of, that the great progress in the water movement, as in the drainage and other improvements for health, is owing to the engineers. Engineers have shown, that water can be cheaply raised, efficiently filtered, and sent into the houses as a constant supply, just in the same way that by improvements in the form and construction of sewers, they paved the way for the extension of the sewage system. Mr. Chadwick has done much; medical men have done much; but the share of the engineers, although little noticed by the public, and purposely kept out of sight by the government, is none the less worthy of regard. As is too common, those who halloo the loudest are those most looked to; and those who do the work, forgotten. It is much harder to lay down a good and cheap sewer than to make an outcry about want of drainage; and yet he who does the work gets the least reward.

This unsatisfactory state of affairs is, to a great degree, dependent on the system of management now adopted, and for this reason in particular we now take up the pen, in the hope of gaining the co-operation of our readers. Hitherto the system has been bad; but care must be taken, that in making alterations, one bad system is not substituted for another; or, indeed, a worse system for what is now bad enough. The water companies have failed to work well,—the Sewers Commission is unsettled,—the Health Commission is only in a provisional state,—the management of streets, paving, and lighting is disorganised.

We know there is one favourite panacea in Downing-street government management; and there is a strong push made to bring it to bear on the water supply, but with no sufficient reason. If there were formerly people weak enough to believe that government management is perfection, that belief is now shaken. Every paper that comes out, gives the fullest and strongest proofs of government mismanagement; and the last year's exposures have been awful. We knew before how bad are the Post Office, the Government Life Annuity arrangements, the Colonial Office, our Foreign relations, the Exchequer Bill Office, the Victualling Department, the Board of Works, and the Railway Commission; but we are now enlightened as to the management of the dock yards and steam navy, the crown forests, the Money Order Office, the Mint, and the Ecclesiastical Commission. Those must be mad, indeed, who trust the government willingly with the management of anything.

As the grand features of government management are irresponsibility to the public and inaccessibility to individuals, and as these are the chief evils of the present water management, we may well hesitate when the transfer of powers is proposed. As, too, the management would be concentrated under the government without any corresponding advantages, the result might be an exchange of King Log for King Stork.

So far for public interests: and as for professional interests, the proposition of government administration bears with it no greater inducements. It is never the object of the government to employ talent; but to work their patronage for political purposes, resorting to talent only in the last emergency. This statement requires no comment, for its truth is within the experience of every one. Further, the government, wherever they can, avoid the employment of civil engineers, and employ military engineers, as the many distressed members of the profession in the metropolis know, to their sorrow. Whereas, in other countries, civil engineers and surveyors are employed to execute the general survey and *cadastre*, here, without any reason, such work is given to the Ordnance department. In the first new Commission of Sewers, not one civil engineer was named; and, in the following Commission, Messrs. Stephenson and Rendel are muzzled by twice the number of military engineers. It is no uncommon thing at the meetings of the Commissioners for no civil engineer to be present, or for one civil engineer to be present and three military engineers. Having seen these things, we do not advocate government management; while so far as we know, the City of London, the Old Sewers Commissioners, and paving boards, do not employ captains and lieutenants, but competent civil engineers and surveyors.

The profession have forced the government to do something to name civil engineers on the Sewers Commission and the National Exhibition Commission; and the wedge, having been thrust in, must be driven home.

As to mock public bodies under the name of independent trusts and boards, they are as bad as regular government commissions; and we may refer to the Old Commissioners of Sewers, the Trustees of the British Museum, the County Magistrates, the Moneyers of the Mint, and the Royal Academicians. These parties, unless it suits them, do not even acknowledge the jurisdiction of the legislature, while the assessments of the county rates and police rates are very unsatisfactory to the rate-payers, who have no remedy but to send deputations to Sir George Grey, which are not always received. A secretary of state is too great a man to listen to parish vestries.

No valid objection lies, so far as we know, to the management by the public of their own affairs. The City sewers and paving are quite as well managed as any; and it is to be presumed the constituency are satisfied, as they are not turning out their representatives, which they have the power to do when displeased. The government have likewise been forced to allow the citizens to be represented in the Metropolitan Commission of Sewers. If the government do not choose to give corporations to Marylebone and Lambeth, that is no reason why the inhabitants should be deprived of the control over their own interests, which is allowed to the inhabitants of Manchester and Birmingham, though neither of these had a corporation before the Municipal Reform Bill. No one will say that the people of Marylebone are less fit to manage their sewers and water supply than the people of Manchester, nor that there is any greater need for government tutelage of the former than of the latter. The people of Marylebone do not ask for government tutelage, but repudiate it, and do not offer to give up to the government the control over the poor, the paving and the gas companies.

Of course the government, whenever public management is talked of, have a holy horror of jobbing; nay, if they durst, they would cast the charge of jobbing in the teeth of the Corporation of London, and the Marylebone vestry. Perfect management can never be got from imperfect human nature, and therefore jobbing may be expected; but at any rate the citizens of London, the burgesses of Manchester, and the inhabitants of Marylebone, job with what is their own, for their own benefit; whereas the government job with what is ours, for their own benefit. There have been some pretty things done in corporations; but while Lord Monteagle, Lord Brougham, and Lord Ellenborough, sit in the House of Lords, the less that is said in high quarters about jobbing the better.

The election of a general Commission may take place either directly by the ratepayers, or indirectly by means of the boards of guardians. The latter way will do well enough for the present.

Instead of one central Commission, which cannot attend to the individual demands of two millions and a half of people, living in more than a quarter of a million of dwellings, we should prefer district Commissions with the power of uniting for any general purpose. To these we would commit the care of the sewers, street improvements, paving, cleansing, lighting, water, and turnpike roads.

Our reason for preferring district Commissions is, that the working of a Central Sewer Commission is not favourable to the plan of one Commission—while no general plan of drainage has been adopted, and no general measure has been carried out, the interests of localities have been neglected. Indeed, what care is likely to be taken of Poplar or Hatcham, by a board on which neither has a representative. Local interests are therefore left to the local officers, who become virtually irresponsible, and set the public at defiance. Poplar may be neglected that Westminster may have the first turn, or Lambeth be made to give way to Pimlico. In the City of London Commission, which exercises all the functions we have wished to see united, each locality has its representative; and the individual can, as he pleases, apply to his own representative, living in his own street, or to the whole court.

The system we have proposed will get rid of the confusion and expense of so many separate trusts as now exist, afford all the benefits of centralisation, and yet be perfectly accessible and amenable to public control,—while it will have a sufficiently permanent character. The system has worked well in the City of London, and there is no reason it should not work well throughout the metropolis.

Of course it is difficult arbitrarily to define new districts, but we think as far as possible the several natural water courses should form separate districts, and the line of division should be taken upon the water shed. The Lea, the Fleet, and the Bayswater brook districts, have few interests in common, and such as there are can readily be arranged by a convention or delegation of the several districts. If a new outfall is to be provided, or some new source for water, a delegation from the several Commissions can very well manage it, as the separate committees of one commission or corporation perform separate functions, so in the City, the Bridge Committee, the Improvements Committee, the Navigation Committee, and the Markets Committee.

Westminster and Marylebone might, we think, form one district, the line of water shed passing by Holborn-hill, and so by the west of the Fleet. The City of London would remain undisturbed. Finsbury or the Fleet valley might form a district, and the Tower Hamlets or the Lea another. On the south the Ravensbourne, Lambeth or the river marsh, and the Vauxhall brook might form the bases of other districts.

SUPPLY OF WATER TO THE METROPOLIS.

On the 4th of February, Mr. Tabberner gave a lecture to a very respectable audience, in Willis's Rooms, St. James's-square, "*On the Sources available for Improving the Supply of Water to the Metropolis.*" The Right Hon. Lord de Mauley presided, and several members of parliament and scientific gentlemen were also present.

Mr. Tabberner commenced his discourse by observing, that there was no necessity for his alluding to the great urgency of improving the water supply of the metropolis: the imperative necessity was universally admitted as the first step to be taken towards the attainment of any comprehensive sanitary ameliorations. Public opinion had very much changed within a short space of time, as to what was to be understood by a *good* supply of water. The quantity now estimated as absolutely essential for the social requirements of the inhabitants of all large towns had increased from 200 to 300 per cent. over the quantity deemed necessary some three or four years since. Without unnecessary preface to his object, he would therefore at once proceed to point out—first, the various means of improving the metropolitan supply afforded by the surface waters adjacent to London; secondly, he would enter into a geological explanation of the structure of the chalk stratum beneath and around London, and its capabilities of affording water to the inhabitants by means of Artesian wells, which he would illustrate by the several diagrams then before them; and, thirdly, expound the great benefits that will accrue to the public socially and fiscally, by consolidating the whole water supply of the metropolis, the drainage and sewerage, paving and lighting, and the regulations pertaining to the erection of metropolitan buildings, under one public commission, directly responsible to the inhabitants and the government conjointly. The lecturer then proceeded to say, that the surface waters available to London principally rose as springs from the chalk formation, by which the metropolis is surrounded, and extending under the alluvial deposits upon which it is built. If we took the south and east of London from the outsides of the inclinations of the chalk basin, we had the rivers Kennet, Loddon, Auborne, Wey, Mole, Wandle, Ravensbourne, and Cray; and on the west and north, the rivers Brent, Colne, Gade, Verulum, Lee, Stort, Ware, and Rodding—all of which took their rise as chalk springs, and grew into important streams and indirect tributaries of the river Thames: the latter taking its rise from several springs in Gloucestershire, and, as they were aware, grew into a navigable stream by the natural drainage of the country through which it wound its course to the metropolis. The quantity of wholesome water available from the above surface sources alone to the use of the London public, would amount to from 200 to 300 million gallons per diem.

The schemes now before the public for improving the general water supply, viz., the Wandle, the proposed improvement of the Lambeth Company's works, by taking their future supply from Thames Ditton; the Maidenhead, the Henley-on-Thames, the Mapledurham, and Watford schemes, were severally explained by Mr. Tabberner, who, of the Thames schemes, gave the preference to the Henley-on-Thames, in consequence of the confluence of the rivers Kennet, Lodden, and Auborne, just above the source of supply; and also because it proposed to place the whole water service under the control of a public commission. As to whether the quality of the water would continue permanently good, and as to whether the navigation of the river would be damaged by the proposed abstraction of 100 million gallons of water every 24 hours, were points to be decided. These, he said, were difficulties to be overcome, which would at least require skill and mature consideration; and concluded the first part of his discourse by explaining the late Mr. Telford's schemes, and the propositions made to improve the New River Company's and the East London Company's supplies, by taking the waters of the rivers Ware, Stort, and Rodding.

Mr. Tabberner then described the alluvial and chalk deposits upon which London was built, and proceeded to urge that the many statements which had gone forth to the public from Dr. Buckland, the Rev. Mr. Clutterbuck, Mr. Braithwaite, and others, were wrong with respect to the alleged failures of many of the commonly-called Artesian wells sunk in and around London—especially the theories of Mr. Clutterbuck. It had been stated that the Messrs. Barclays and Messrs. Calverts were now compelled to work alternate days on account of their interfering with each other's wells: there was not a particle of truth in such a statement. Originally, when both their wells were sunk only into the sand above the chalk, they undoubtedly did affect each other; but since Messrs. Barclay had sunk 153 feet into the chalk, they had had an uninterrupted supply of water. The quantity had, however, somewhat diminished since 1843, owing to a fact important to be known. When they first sunk the bore-pipe into the chalk, they at the same time continued to avail themselves of the water afforded in the sand, by perforating that portion of the pipe which passed through it; the sand had consequently percolated through those perforations with the water, and had precipitated down, and become consolidated in the pipe of the chalk to the extent of 73 feet, and had stopped the free passage of the water from the fissures of the chalk. A short time since the pipes had been cleaned out, and the water had since gradually risen. He had no doubt that many similar unascertained casualties existed. Mr. Tabberner then gave a description of the capabilities of the Trafalgar-square works, showing that when they were quite completed they would be able to afford from 1,000 to 1,200 gallons of water per minute, a supply which would be sufficient to furnish the Serpentine River, the Barracks round the parks and at the back of the National Gallery, the Fountains in Trafalgar-square, the Queen's Palaces, the Houses of Parliament, the whole of the Government Offices, the Baths and Wash-houses in St. Martin's-in-the-Fields, &c., at an annual charge of from 1,200*l.* to 1,500*l.* less than such a supply would cost if taken from the Chelsea Water Company. The whole outlay would be about 18,500*l.*, and the annual working expenses 1,000*l.* He further adduced many facts, showing, by carefully prepared diagrams of the principal deep wells, and of the sand and chalk strata, at what depths beneath the London clay an uninterrupted supply of water might be obtained, and where and

how the elevations of the chalk beneath the clay interposed difficulties in obtaining a supply of water; clearly demonstrating that it was the water in the sand-bed above the chalk, and not the water in the depths of the chalk, that was limited in quantity; and describing how, from the declivity of the chalk formation, the fissures thereof under the alluvial deposits discharged the water into the sand; and how the wells sunk only into the sand were more or less subservient to each other.

A discussion here arose between Mr. Braithwaite and the lecturer, the former endeavouring to prove that the increased quantity of water at Covent-garden market had been obtained by improving and lowering the pumps of the well, and not altogether by sinking the bore-pipe into the chalk.—Mr. Tabberner said he was not contending for the mechanical superiority of one engineer over another, but for the demonstration of the fact that for many years Mr. Braithwaite had been endeavouring to obtain a sufficient quantity of water for the market out of the sand-bed above the chalk, and that he had not succeeded. Messrs. Easton and Amos had subsequently bored 90 feet into the chalk, and thence obtained a bountiful supply of water. This instance, and many others which Mr. Tabberner adduced, showed that Mr. Braithwaite was wrong in his supposition that the principal body of water was to be found in the sand and not in the chalk.

Mr. Clarke, who had bored a great number of wells in and around London, and who was then engaged in extending the boring of the Southampton deep well, here rose to support Mr. Tabberner's views. He had frequently bored considerable depths into the chalk without obtaining water; but by continuing to bore deeper he had always ultimately found an abundance of water.

Mr. Tabberner then proceeded to describe the quality of the chalk water, showing that reports as to its hard and chalybeate qualities were not founded in truth. The carbonate of lime and magnesia, which were the hardening constituents, did not amount to 6 grains in the gallon, while the same constituents in the Thames water amounted to from 10 to 12 grains in the gallon. He further urged that the other properties contained in the chalk water were essentially wholesome, and necessary to the natural support of the human body. The rain as it fell on the exposed surface of the chalk was *pure* water; but as it percolated through the chalk fissures, it took up in its course, in a greater or less degree, the carbonate of lime, magnesia, the alkaline, and other constituents he had alluded to. He distinctly contradicted the groundless supposition that the sea water found its way into the deep wells of the chalk under London, and denounced the idea as a theory perfectly fallacious and untenable.

Mr. Braithwaite here again denied Mr. Tabberner's last position to be correct, and gave Professor Brande as his authority. He said, all deep wells, the water of which did not rise to the level of Trinity low-water datum, were affected by the sea-water percolating into them, and instanced the deep wells at the Mint and Trafalgar-square respectively, as producing water so affected.—Mr. Tabberner took Mr. Braithwaite's own authority, Professor Brande; and from a paper of the latter lately published, showed that the solid contents found in the water of the well at the Mint, were 38 grains in the gallon; and that the solid contents found in the water at Trafalgar-square, were 68 grains in the gallon. He contended that Mr. Braithwaite was again in the wrong; the salt and alkaline properties of both wells differed in the same ratio, and there were no two wells alike. He, Mr. Tabberner, therefore submitted, whether, if both these wells—indeed all the deep wells—produced sea water, they would not be identical in their constituents: the fact of their not being so would not justify Professor Brande, Mr. Braithwaite, or any one else, in the supposition that the water in the deep wells, or what was commonly called Artesian wells, as sunk into the chalk formation under London, were impregnated with sea water.

Mr. Clarke here said, that he had bored the well at the Mint, and that Professor Brande had told him that the water raised from it was very pure.

Captain Moorsom asked Mr. Tabberner, whether it was not true that many of the London brewers had been in great difficulties with regard to their supply of water from the chalk; and if they had not been compelled to deepen their wells?

Mr. Tabberner said they had, as he had already admitted; and it would be contrary to common-sense and the natural laws of hydraulics, to suppose that the level of the water of the chalk did not lower as the number of wells sunk into it increased. There was but an average of 21 inches of rain fell upon the chalk surface; and supposing only 10 inches of the whole quantity percolated through the fissures into the depths of the chalk, only that quantity could be found in it; and supposing that first 100 wells were sunk, then 200, then 500, and so on, it was very natural and a necessary deduction, that the original level of the water would be gradually lowered; but as the wells were deepened into the vale of the chalk formation, the water would be found in proportion to the depths in greater abundance, and the general level of the water contained in the fissures would vary according to the quantity of rain and snow falling on the exposed surface of the chalk; and in proportion to the quantity of rain so falling, repletion would be afforded to the wells—and he had no doubt in his own mind, that from 400 to 500 million gallons of water might be raised from the depths of the chalk stratum per diem. He estimated the cost of an Artesian plant, consisting of 100 wells and engine power, 1,200 miles of 7-inch main piping, and the contingencies pertaining to an undertaking competent to supply from 30 to 50 million gallons of water every 24 hours, at 1,700,000*l*. The annual cost of a continuous high and low service to every house, he estimated at about 70,000*l*., or about 1¾*d*. per 1000 gallons.

Mr. Tabberner concluded his lecture by a statistical exposition of the saving that might be effected to the public, by taking the water supply out of the hands of trading bodies, and hereafter placing it under the control and management of a public elective board, as public property, subjected to the supervision of government. He would first urge upon the government the necessity of introducing a measure into Parliament, which should provide for such a board, with powers to raise money upon the future rates, to be equally levied according to the assessment upon every house throughout the metropolis, the ground landlords being made liable for the rate, which liability should enjoin compulsory powers to extend the water supply to every house, and to make such supply a part and parcel of the fee-simple; while every site applied to future erections of any denomination whatever, should be chargeable with the cost of extension of water-service mains and pipes to such property as it was used for building purposes. He would then raise sufficient means to purchase the plants and interests of the existing companies, which he would turn to sanitary purposes, and provide an entire new continuous plant for domestic purposes, the whole cost of which he computed at about 4,500,000*l*., which he stated might be raised without asking government or the rate-payers for one shilling, while the average rates might immediately be reduced very considerably. Thus would be restored to the inhabitants that indefeasible public right to this first necessity to man's subsistence, which was formerly enjoyed by the citizens of London prior to the corporation transferring that right to commercial speculators. Mr. Tabberner set forth his calculations in the following form:—The present population was 2,336,000; and dividing that number by 7 (the mean number of inhabitants, according to the Registrar-General's Report, to every house), the number of houses comprising the metropolis, would be 333,000 houses, or say, for the sake of round numbers, 330,000, to each of which he would supply an average of 175 gallons of water, or 25 gallons to each individual of a population of 2,336,000, every day, at an average annual cost of 8*s*. per house, estimating the cost of water (in accordance with the prime cost to the existing companies, and also of the proposed new schemes), at 1½*d*. per 1000 gallons.

	£
This average rate of 8*s*. upon 330,000 houses, would produce	133,000
To pay 4 per cent. on 4,500,000*l*., he would require an additional average rate of 11*s*. 3*d*. on 330,000 houses, which would produce	180,000
To raise a liquidating fund to pay off the 4,500,000*l*. borrowed over a term of 30 years, he would require a further average rate of 6*s*. 3*d*. on 330,000 houses, producing	100,000
Or a total average rate of 25*s*. 6*d*. per house, producing a gross annual revenue of	£413,000

This average rate of 25*s*. 6*d*. per house would be gradually reduced as the progress of annual liquidation went on, till the whole debt was discharged, and the whole water supply became free to the inhabitants at the mere cost of conveyance, which result, under good and economical management, would be accomplished in a much less term than 30 years.

The average rate for every house supplied by the present companies was, in the year 1833, 30*s*. 10½*d*., 5*s*. 4½*d*. more than the total average required by Mr. Tabberner to accomplish all he proposes; and presuming that the average rate now charged by the companies is not less than it was in 1833, it will appear that the

annual cost of the present water supply to only 259,668 houses (the number of water tenants given by Sir William Clay), is 391,124*l.* 18*s.* 6*d.*, or little under 22,000*l.* less than the annual revenue required by the lecturer to supply 330,000 houses, and to pay off all the sum required to afford an entire new service for domestic uses, and to purchase the plants of all the present companies for sanitary purposes.

Mr. Tabberner proposed, that the public commission under which this beneficial sanitary institution should be established, and by which it should be worked, should be composed of property-qualified ratepayers, four or six out of every electoral district, to be periodically elected—say one-third to retire every three years, and to be eligible to be re-elected; which commission should appoint an acting paid committee, not members of the commission, but practically-qualified men, as public servants,—which committee should be bound constantly to attend, and to devote the whole of their time to the business of the commission, aided by not more than two government inspectors, through whom the commission should be made responsible to government through the medium of the Board of Health: thus producing a power of control directly responsible to the inhabitants and to the government. And in addition to the water supply, he would place the control and management of the sewerage and drainage, paving and lighting, and the erection of metropolitan buildings, under one and the same commission; thereby secure efficiency, uniformity, and economy, and, he believed, in a very short space of time, an annual saving of the public funds of not less than 300,000*l.* He also suggested, that it would be well to make such a Bill as he proposed, compulsorily applicable to every town and city in the United Kingdom; each place to be divided into districts, and each commission to be elected in numbers according to the amount of population, and the whole also subjected to an inspection responsible to government through the medium of the general Board of Health.

REMARKS

ON THE PLAN PROPOSED BY THE

METROPOLITAN COMMISSIONERS OF SEWERS

FOR THE

DRAINAGE OF THE SURREY SIDE OF THE METROPOLIS.

"At present there is a prevailing approach to agreement in the Sciences, founded on observation of outward nature. When controversies arise in these Sciences, they [illegible] generally confined to limited questions, and to points upon which attention has been recently turned, and after a time they are settled by investigation and reasoning."—LEWIS. 'Essay on the Influence of Authority in matters of Opinion.'

"It has been shown in matters of drainage, that the economy and efficiency of the works will be according to the qualifications, the powers, and the responsibilities of the officers appointed to execute them, secured by legislative means; and that new labour on the old condition, without skill, will be executed in the old manner, extravagantly and inefficiently."—EDWIN CHADWICK. 'Report from the Poor Law Commissioners on the Sanitary Condition of the labouring population of Great Britain.' 1842.

At a meeting of the Members of the Metropolitan Sewers Commission, held at the Chief Office, Greek-street, Soho, on the 25th of January last, the following resolution was put from the chair by Sir Henry De la Beche, and carried:—

"That it be recommended to the court that the engineer be instructed to prepare estimates for the consideration of the Commissioners, for a plan of the drainage of the Surrey side of the Thames, with reference to a covered channel for general outfall, between Vauxhall and Deptford, or thereabouts, by which the present distance by the river will be shortened, and a better outfall secured; to the continuation of the channel to and beyond Woolwich, and to the removal of the whole sewage of such area from that part of the Thames, due attention having been had and being paid to those plans sent into this Commission which relate to the same area."

We may therefore shortly expect a detailed communication on the subject from Mr. Frank Forster; and as, in the event of his estimates being deemed satisfactory, there is not merely a possibility, but a probability, of the proposed scheme being carried into effect, we take an early opportunity of making a few brief observations on the merits of Captain Vetch's plan, which, we hope, will at least have the effect of directing the attention of the public to the necessity of mature consideration being given to so important a subject before any plan is finally adopted.

All we are in possession of as yet respecting the proposed plan for the drainage of the Surrey side of the metropolis, is principally contained in the reported speech of Sir Henry De la Beche, delivered at the meeting of the Commissioners above alluded to. We shall therefore confine ourselves strictly to the statements made by Sir Henry, and consider how far such statements are likely to lead us to hope for such effectual drainage of the south side of the river as the public have a right to expect from the Commissioners and their engineer.

It was with no small degree of satisfaction, after the published opinions of Sir John Burgoyne and others of the Commissioners, that we saw the report in the *Times*,[1] headed "Drainage of the Metropolis—*Purification of the Thames*;" and the opinions of Sir Henry respecting the importance of the non-pollution of the Thames fully stated. He concludes this important part of his address with the following sentence:—"Under all these points of view, it seemed essentially desirable that they (the Commissioners) should be instrumental in removing the sewage from the Thames." This is most satisfactory: it settles the important question—"Is the Thames to be polluted, or not?"—"No."

In considering the manner of draining a district, the matter of consideration that deserves our first attention is, that of a sufficient outfall; and the question naturally arises, what natural outfall or outfalls does the district and its neighbourhood afford? Of outfalls there are three different kinds: first, there are natural outfalls immediately connected with the district under consideration, which again divide themselves into available outfalls and unavailable outfalls, according to the conditions imposed on the engineer—viz., according to the object or objects, whether direct, indirect, or both, for which the drainage is contemplated. Secondly, natural outfalls, not immediately connected with the district to be drained, requiring an artificial conduit of communication between the area to be drained and that possessing the necessary sufficient outfall. Thirdly, artificial outfalls.—Let us consider the case in question. We have, in the first place, a natural outfall in the river Thames, encircling, as it does, nearly the whole of the western, northern, and eastern sides of the district. Is it an available outfall or not? That the Thames is not to be polluted by the admission of sewage matter into its stream, is at length acknowledged by the Commissioners themselves. "They," says Sir Henry De la Beche, "should recollect that the sewage, according as the population had increased, was more abundant in the Thames than formerly. Good as the 'flushing system' was in many points of view, it had added to this evil, inasmuch as the matter which was previously collected and removed by hand, was now thrown into the Thames. Another point to be considered was, that since the erection of London-bridge there was a difference of 3½ feet in the height of the water above the bridge, and which had been a source of considerable annoyance to the population." Under "all these points of view," adds Sir Henry, it seems "essentially desirable" that the Commissioners "should be instrumental in removing the sewage from the Thames." Under these considerations, the natural outfall of the district of Southwark becomes an unavailable outfall. But there are other reasons why the Thames should be rejected as a receptacle for the sewage of this portion of the metropolis. It is a tidal river, and portions of the district are below high-water mark; from which circumstance it follows, that whatever means be adopted for draining the said area, making use of the Thames for an outfall, the mode of operation must inevitably become intermittent instead of constant—the sewers and drains becoming cesspools during portions of each day. Moreover, the length of time during which, in such a case, the sewage would have to remain confined within the drains, would be in an inverse ratio with the inclinations, and, consequently, "effectiveness," as regards discharge, of the whole system of drains; or, in other words, according to the height of the cill of the outfall-end of the main sewer. It is true, that by proper trapping much of the evil attending an intermittent plan of draining can be remedied; but no system of sewerage can be deemed really good that is not constant. Well, then, the Commissioners have agreed most judiciously—not to say of necessity—not to make use of the only natural outfall presented by the district. Of neighbouring outfalls (the second class before alluded to) there are none at all available along the line of coast: artificial means, therefore, become indispensable.

Let us now examine the plan proposed by Captain Vetch, for the thorough drainage of the Surrey side of the river.

Sir Henry De la Beche began his observations to the Commissioners by calling to their recollection, that when they first took office under the present Commission, it was intimated to them that the subject of the drainage of the Surrey and Kent side of the river had received very considerable attention. "During the existence of the previous Commission," continues Sir Henry, "there had been a committee, termed the 'Ordnance Survey Com-

[1] "Times" of Saturday, January 26th.

mittee,' four members belonging to which were members of the present court. During this time the Ordnance Survey Committee had been engaged in that part of the metropolis, and were constructing the network of levels. It was thought to be extremely desirable that three or more points of the river should be connected with such levels, to ascertain the height of the tide. The result has been the production of a very valuable collection of facts and documents, from which it would appear that they should even think of constructing the lines and shortening the distance between Battersea and Deptford. The minimum difference in the tide between these places was 2½ feet. It was obvious that by shortening the distance they would accomplish a better fall, if that were needed." Sir Henry might well have saved himself the trouble of going into these details, since from his own statement, fully given, a fall of any kind into the Thames cannot only not be needed, but is of necessity to be avoided. But let us continue. Sir Henry "thought he might mention what was, no doubt, known to the Commissioners, that a valuable body of information was collected by Mr. Page, for the Metropolitan Improvement Commission, and which was printed in their reports. Part of it was original, and part contained in other documents, &c.; but he (Sir Henry) referred to it as embodying a mass of valuable matter." No doubt about it. "The attention of Captain Vetch had been especially directed to the formation of a scheme for the drainage of the Southwark side of the river Thames. He wished it to be particularly noted, that all this occurred previous to the former Commission requesting plans to be sent in for the drainage of the metropolis. With respect to the scheme for taking the shorter line on the north and south side of the river, and so partially reversing the drainage, in this there was no great novelty. So far as ten or eleven years ago, he believed that Mr. Thomas Cubitt had proposed a scheme of that kind, which was quoted by Mr. Walker, in his evidence in 1840, on the state of the Thames. This was not the first scheme which included the stopping of the drainage by the river, because Mr. John Martin had previously completed the scheme for drainage on both sides of the Thames. With regard to the south side, their object had been to obtain a fall by shortening the distance, and the opportunity of flushing the main channel and any branch channel, without, as now, discharging all the sewage into the Thames; and afterwards affording the opportunity of distributing the sewage manure by various lines of railway, as the wants of the public should demand, supposing the drainage should cut the lines of railway."

What are we to understand from all this? Sir Henry, in one part of his speech, most emphatically expresses his opinion as to the necessity of no longer polluting the bed of the river with the filthy discharge of any portion of the sewage of the metropolis; and in the next, advocates an outfall into the said river, because an "advantageous" additional fall of 2½ feet can be obtained by taking a shorter course. As to Sir Henry's statements respecting the evils attending the use of the Thames as an outfall for the sewage of London there can be but one opinion. The writer of a leading article in the *Times* of the 28th January last, observes, "In the first and foremost place, it [the resolution passed at the meeting] contains the deliberate acknowledgment of the Commissioners, that the river Thames should no longer be retained as the main sewer of the metropolis, but should be drained and cleansed like any other infected locality." And in order to effect this draining and cleansing of the bed of the river, it is now proposed to pour into its stream at Deptford, or may be Woolwich, at low water, all the refuse of the densely-populated district lying between Battersea and Deptford, that will not have been carried away by rail for agricultural purposes, "supposing the drainage should cut the lines of railway."[2]

Even admitting the extension of a conduit from Deptford to Woolwich,—and Sir Henry does not even allude to the subject in his speech,—and thereby the removal of the Southwark sewage beyond the boundary that divides Surrey from Kent, we need hardly add that the reasons for discontinuing the pollution of the Surrey and Middlesex banks of the river must surely apply equally powerfully to the Kent bank, bordering so densely populated a district as that lying between Deptford and Woolwich; particularly when we take into consideration that a discharge of sewage, wherever made on the south side of the river, has to meet with the influence of an up-tide, consequent on such discharge taking place inevitably, on account of the lowness of the district, at low water. Sir Henry, who had occasion some years ago, he tells us, to consider the distribution of sewage into estuaries, and who agrees with Sir John Burgoyne, "that the Thames being an estuary, all the effects that take place in an estuary must occur in it also," will of course understand most readily the results which we are likely to anticipate from a removal of the refuse of Southwark into the bed of the Thames, whether at Deptford or Woolwich, at low water;[3] and from the action of an up-tide, immediately after its discharge. We cannot do better than borrow Sir Henry's own words. "The sewers discharged their contents into the Thames at low water; at that time the water being stagnant, the sewage was discharged into the river according to its velocity, but on the first motion of the water, it (the sewage) had a tendency to go along both sides of the river, and two masses of filth were thus trailed along the banks. This was composed of matter in chymical solution, and mechanical suspension. Now these two masses passed along both shores and went as far as the tide would carry them."[4] This is precisely what takes place; and in the case before us proposed by Sir Henry, the sewage of a large and populous district will be discharged into the Thames at Deptford, at low water, according to its velocity: the water in the river at the time being stagnant. On the first motion of the water, it (the sewage) will have a tendency to go along both sides of the river, and two masses of filth will thus be trailed along both banks. This will be composed of matter in chymical solution, and mechanical suspension. And these two masses will pass along both shores and will go as far up the river as the tide will carry them—and we may add, taking the more populated and important part of the metropolis on their way.

In addition to this, we find that the Thames is not only to be polluted with the discharge of the Southwark sewage, but that at a meeting of the Commissioners on Friday, the 8th inst., a sewer through a considerable portion of Westminster, discharging itself into the Thames, was determined upon, on the recommendation of Mr. Frank Forster, and is about to be carried into effect.[5] So much for the statements of Sir Henry De la Beche, as to the general wish of the Commissioners not to pollute the Thames with sewage matter. The writer in the *Times*, already quoted, hoped for better things when he wrote:—"Our very words are now almost snatched from our mouths by these eager converts. 'There is no reason,' says the Chairman, 'why artificial means should be adopted to add to the noxious qualities of the river mud.' None in the world, certainly.—'It gets moistened with the sewage matter, and that adds to the disagreeableness of the filth.' Not a doubt about it.—'Looking on shore, too, this deposit is sure to be discovered in situations most inconvenient to the inhabitants.' Of course it is. As the American engineer said, 'It seems to take a pleasur' in gettin' there.'—All these are axioms, if of a somewhat elementary, yet of a most unquestionable character, and we are only too glad to see them at length formally recorded." Yes "recorded"—and that is all.

"But," it might be argued, "it is not the intention of Captain Vetch and the Commissioners to make use of the proposed outfall exclusively for the purpose of a means of discharge into the Thames: they hope the demand for liquid manure will be such as to prevent almost entirely the pollution of the river." If so, we can see no necessity for the expense of a main sewer from Battersea to Deptford, with a continuation to Woolwich—no small amount of work to execute. For the purpose of transport into the country, mechanical means of some kind must be employed for raising the diluted refuse from the low levels at which it will be confined, whether the principal outfall be at Deptford, Woolwich, or elsewhere; and surely there can be no kind of apology for wasting the public money in constructing expensive works, from which no advantage can possibly result, that could not be obtained for a far less sum, without such a main sewer. If the Thames is really to be rejected as an outfall, an artificial outfall becomes

[2] Purely conditional on accidental circumstances.

[3] And if we take into consideration the depth of some of the basement stories in some of the lowest parts of the district, in connection with the question of sufficient fall for branch drains, we think Mr. Forster will not find low water mark at Deptford much too low for the invert of his sewer.

[4] "Nothing could be more beautifully expressive than this description. To be sure it was somewhat superfluous, and resembles a little that technical certificate of Death's doings which the medical witness offers to a coroner's jury:—Deceased having been found hanging, it is proved that the articulation of the cervix with the occiput has been disordered, and that great extravasation is discoverable in the brain,—facts, doubtless of great importance, but not adding much to the convictions of those who had cut the poor wretch down, stone dead. We citizens can see but too plainly how the sewage haunts our banks, and are perfectly willing to believe that the result is in accordance with the eternal laws of an estuary. All we ask is a verdict in our favour."—"Times," of Monday, January 28th.

[5] Let the rate-payers look to the new Westminster sewer. It cannot be an inexpensive work, and it is sure to be either a superfluous or an inconvenient one. We admit that such accommodation cannot be delayed until the present problem is solved; but all this expenditure for provisional convenience will become little more than a dead loss when the entire system of sewerage is re-modelled. It is clear enough that we cannot cleanse the Thames in a day, but it is surely time to cease paying our thousands of pounds in order to vitiate it more thoroughly."—Conclusion of a leading article in the "Times," of Saturday, February 16th.

indispensable; and consequently there can be no possible use for a main sewer such as the one proposed. A great objection to what are called first-class sewers, too, is their great size, which renders them as inefficient as they are expensive. A well matured system of drainage should be properly graduated for the effectual removal of all refuse matters under well calculated, mean ordinary circumstances; and for all other cases, such as those of extraordinary floods, other means of removal should be provided, since no same sewer can possibly be made to act with maximum efficacy under the very dissimilar cases of limited or ordinary, and extraordinary discharge. And surely of the two, we should give the preference to efficacy under usual conditions of supply. To wish therefore to build sewers large enough under any circumstances, not only shows a complete ignorance of the first laws of hydraulic science, but argues a want of common-sense on the part of the projector. What—if we were to object to the human organisation, on the ground that the digestive organs merely provide for the digestion of the ordinary amount of food necessary for the purposes of life, on the score of the inconvenience attending indigestion, caused by no provision having been made in cases of surfeit of food—of extraordinary "feeds"? Our metropolitan sewers have been constructed capacious enough for all possible cases of indigestion; but, unfortunately, the gastric juice required—hydraulic pressure,—has been found to lessen with the increase of their sectional areas; deposits have taken place—accumulations of solid filth have blocked them up—the whole fabric has been found not only ineffective, but a public nuisance, alike dangerous to the health and morals of a large portion of the population.—What the remedy? Scouring.—The consequence? A series of intermittent cesspools. And is such a system still to be carried on? The public money expended in creating a still greater number of longitudinal receptacles for filth? We hope not. We would lay down as a rule that the minimum sufficient drain, for all ordinary purposes, whatever its class, is the one that should of necessity, on the mere principles of economy and common-sense, be adopted. We do not presume to settle the questions what the sizes of minimum sufficient drains should be under various circumstances, and for the different classes of house, street, court, and main drainage; but this we wish to be understood clearly, that, until minimum sufficient drains are adopted, maximum hydraulic pressure cannot be obtained—and unless maximum hydraulic pressure be obtained, maximum scouring-power and efficacy cannot possibly be realised.

Mr. Rendel, in his address to the Board, after seconding the motion made by Sir Henry De la Beche, said: "He had no doubt that when practical engineers were put upon the Board, something practical was intended should be done. He believed something practical would be done from the present time, and he thought that while acting so, they would have the public with them." We may be allowed to observe to Mr. Rendel that the putting of practical engineers upon the board, was no kind of reason for at all concluding or believing that something effectual and satisfactory, as well as practical, would be done in the matter of the drainage of the metropolis. Something "practical" was done, when practical engineers were consulted and employed to construct the various sewers now existing,—something "practical" was done when some of the leading practical engineers of the day were asked to report on the efficacy of these existing sewers—when they perambulated them, where possible—and expressed themselves fully satisfied! But unfortunately the "practice" in matters of drainage, which has prevailed in England up to the present time, is proved to have been most defective and unsatisfactory. The actual state of the drainage of London, after the enormous sums that have been expended upon it, is a sufficient warranty of the ignorance of our practical engineers respecting the principles that ought to have guided them in the framing of plans for actual execution. The Sanitary Commissioners express themselves on this subject, in the following words:—"The more the investigation advances, the more it is apparent that the progressive improvements and proper execution of this class of public works, together with the appliances of hydraulic engineering, cannot be reasonably expected to be dealt with incidentally or collaterally to ordinary occupation, or even to connected professional pursuits, but *require a degree of special study which not only place them beyond the sphere of the discussion of popular administrative bodies, but beyond that of ordinary professional engineering and architectural practice.* In justification of this conclusion, and to show the evil of the perverted application of names of high general professional authority, we might adduce examples of the most defective works, which have received their sanction."[6]

And further, "It will be evident to any one who has followed the course of the inquiries relating to Public Health works, that the principles that have been established for future operations will render inapplicable much of the experience that has been formed in the execution of works of house, street, and land drainage, water supply, and general cleansing."[7]

However precise and satisfactory the present state of hydrostatical engineering (and no better proof of the satisfactory state of this branch of science need be adduced than the success Mr. Rendel himself has met with, in the construction of some of the most important dock-works connected with this country; we may also instance the lifting of the tubes of the Britannia Bridge by hydrostatic pressure), the branch to which draining essentially belongs—hydrodynamical engineering—is as yet completely in its infancy, and little help can be derived from the "experience" of past ages. Bulky and numerous as are the writers, both English and foreign, on hydraulics, little or nothing, as yet, is known of the principles which regulate the flow of fluids. The great Newton himself failed[8] to grapple with this truly intricate subject. He invented the method of Fluxions, which enabled him to establish a theory of lunar motions; but he found himself reluctantly obliged to rest satisfied with a mere approximation, instead of a complete solution, respecting the motion of three bodies mutually influencing one another; and this convinced him how hopeless was the chance of ever accurately investigating the laws that regulate the motions of fluids where innumerable atoms comprise their respective influences on each other. "Newton," says Professor Whewell, in his 'History of the Inductive Sciences,' "treated the subject theoretically in the 'Principia;' but we must allow, as Lagrange says, that this is the least satisfactory passage of that great work." Formulæ, to be depended upon for future works of drainage, must be deduced from correct experiments. No data of value can possibly be obtained, but from thoroughly checked tables of correct trials; and upon correct practical results only ought we to depend for the framing of formulæ to work with." Experiments on the flow of water through tubes, have, we believe, been carried on by order of the Commissioners. This is a step in the right direction. The practice which will have to guide us must be founded on such experiments, and we have little to expect from the mere past experience of our practical men; indeed we should rather shun the prejudices which generally accompany the constant treading in the same beaten path.

We have a new field open to us, with great difficulties to contend with, for as yet we have neither theory nor practice to guide us. Our theory has to be founded on correct experiments: our practice on correct theory. Sir John Herschell expresses himself with his usual clearness and simplicity on the subject: "It is a remarkable and happy fact, that the shortest and most direct of all inductions should be, that which has led at once, and almost by a single step, to the highest of all natural laws—we mean those of motion and force. Nothing can be more simple, precise, and general than the enunciation of these laws; and their application to particular facts in the descending or deductive method, is limited by nothing but the limited extent of our mathematics. It would seem, then, that dynamical science were taken thenceforward out of the pale of induction, and transformed into a matter of absolute *à priori* reasoning, as much as geometry; and so it would be, were our mathematics perfect and all the data known. Unhappily, the first is so far from being the case, that in many of the most interesting branches of dynamical inquiry, they leave us completely at a loss. *In what relates to the motions of fluids, for instance, this is severely felt.* We can include our problems, it is true, in algebraical equations, and we can demonstrate that they contain the solutions; but the equations themselves are so intractable, and present such insuperable difficulties, that they often leave us quite as much in the dark as before. But even were these difficulties overcome, recourse to experience must still be had to establish the *data* on which particular applications are to depend; and although mathematical analysis affords very powerful means of representing in general terms the data of any proposed case, and afterwards, by comparison of its results with fact, determining what those data must be to explain the observed phenomena, still, in any mode of considering the matters, an appeal to experience in every particular instance of application is unavoidable, even when the general principles are regarded as sufficiently established without it. *Now, in all such cases of difficulty, we must recur to our inductive*

6 1st Report of the Met. San. Comm., p. 5.

7 Circular Letter to Candidates for Inspectorships, p. 2.

8 Principia, Book 2, Prop. 37, 1st Edit., 1687, and the 2nd Edition of 1714, which contains Newton's altered treatment of the subject.

9 "The science of the motions of fluids, unlike all other primary departments of mechanics, is a subject on which we still need experiments to point out the fundamental principles."—Whewell.

processes, and regard the branches of dynamical sciences, where this takes place, as purely experimental. By this we gain an immense advantage,—viz., that in all those points of them where the abstract dynamical principles *do* afford distinct conclusions, we obtain verifications for our inductions of the highest and finest possible kind. When we work our way up inductively to one of these results, we cannot help feeling the strongest assurance of the validity of the induction. *The necessity of this appeal to experiment, in everything relating to the motions of fluids on the large scale, has long been felt.*"

We have thought proper to enter thus fully on the actual state of hydrodynamical engineering in connection with its own particular branch—the drainage of towns, and the little reliance to be placed, henceforth, in the experience and practice which has produced the defects in, and evils of, the present existing works; and which it is the business of the Metropolitan Commissioners of Sewers to remedy, because we find there is a leaning on the part of the "practical men" Mr. Rendel alludes to, to continue pursuing the old track. "For his (Mr. Rendel's) own part, he felt he could go with the opinion as to avoiding drainage into the Thames, *as far as it could be avoided, in reference to obvious and practical conclusions.*[10] He did not go one jot further; therefore while he went to the full extent of desiring to purge the Thames from the sewage of London, he must be certain that when the plan was carried out, that result would be obtained.[11] He believed, that the plan they had to-day before them, would go a great way in furthering this object; it would, at all events, be a step in the right direction." And yet it is an imperfect plan on the old intermittent principle, with a fall into that river, of whose purification we have heard so much stated by the Commissioners. Though unsatisfactory, our present knowledge and practice in matters of town drainage, we would still add, with the writer in the *Times*, already quoted:— "If the science and resources of the 19th century are incompetent to effect the drainage of the metropolis, otherwise than by its river, *so it must be; but let us ascertain the necessity, before we put up with its consequences.*"

In conclusion, the plan proposed appears to us defective,—

Because the sewage of the whole portion of the metropolis, lying south of the Thames, is to be poured into the river, thereby polluting it, at one of two highly-peopled districts; and

Because this discharge taking place at low water, involves the consequences attending the effects of an up-tide thereon;

Because a provision being made for flushing the branch-drains, implies the possibility of periodical cesspools;

Because the provision for flushing the main sewer, implies the intermittent instead of the constant system of draining;

Because of the impropriety of "flushing" manure already sufficiently diluted with an ample supply of water;

Because in the event of the sewage of the district being required for agricultural purposes, the main sewer from Battersea to Deptford, and its continuation to Woolwich, becomes a waste expenditure;

Because of the expense attending such a scheme.

10 "We readily accept the condition, and consent to ask for nothing impossible."—Leading article of the "Times," Monday, January 28th.

11 "When we advocate the purification of the Thames, it is with the same 'sine qua non' as that alleged by Mr. Rendel, 'that the result,' namely, 'should be really obtained.'"—"Times," January 28th.

WELL WATER.

Analysis of the Well Water at the Royal Mint, with some Remarks on the Waters of the London Wells. By Professor BRANDE, F.R.S., V.P.C.S., &c. (Extracted from a paper read before the Chemical Society of London.)

In consequence of the defective supply of water at the Mint, Professor Brande was consulted on the best mode of obtaining a necessary supply of pure water for that establishment. He was authorised by the master of the Mint to consult with Mr. Thomas Clark, an experienced well-engineer, in reference to the subject; and accordingly desired him to examine into the condition and capabilities of all the wells, shafts, and tunnels, connected with the supplies of water throughout the building. This examination was carefully and effectually accomplished, and it appeared that the several wells were in a very dilapidated, and some of them in a very dangerous state: that few of them were so situated or conditioned as to admit of being sufficiently or safely deepened, so as to yield an adequate supply of water; and that, as respected the wells in the several engine-houses, they were mere reservoirs connected with the tunnel-shaft from the tower, and therefore almost exclusively supplied from the muddy source of the Tower moat.

Having personally convinced himself of the correctness of this report, and having had Mr. Clark's statement corroborated by Mr. George Rennie, he represented the matter in detail to the master of the Mint, and suggested three plans for consideration, namely:—

1. To derive the requisite supplies of water from the water companies.—2. To repair the present wells, and to deepen such of them as would admit of that operation.—3. To sink an entirely new well.

Professor Brande strongly urged the adoption of the latter alternative, which after due consideration, was agreed to. He therefore obtained proper plans and estimates from Mr. Clark, which after having been submitted to the Board of Works, and by their direction to Major Jebb, were ultimately ordered to be carried into execution.

It may be right to premise, that the total depth of this new well is about 426 feet; that the depth from the surface down to the chalk is about 224 feet, and the borings into the chalk about 202 feet; the following being the well-sinker's account of the strata gone through, namely:—

	Feet.
Made earth	*11
Gravel and sand (with water)	15
Blue clay, with a few sandy veins (no water)	98
Coloured sand and pebbles (abundance of water)	14
Dark sand, with veins of clay (little water)	4
Mottled clay (dry)	6
Loamy sand and dark clay (little water)	5
Blue clay, with shells	5
White rock (quite dry)	3
Green sandy rock and pebbles (dry)	5
Loamy green sand and black pebbles (little water)	5
Green sand and pebbles (abundance of water)	6
Dark sand, with shells	40
Flints	10
Chalk	203
	426

The lining of the upper part of the well through the gravel and into the blue clay, is composed of stout cast-iron cylinders, 1½-inch thick, and eight feet clear diameter; they are made in five feet lengths, with internal flanges three inches wide, packed and jointed with strong bolts and nuts; these prevent all access of the land springs from above. The shaft is then steined to the depth of 88 feet (that is, nearly through the blue clay,) in 9-inch cemented brickwork; after which, cast-iron cylinders are resumed of seven feet diameter, and these are continued down to the chalk; but after passing through the stratum of mottled clay, they include a series of cylinders of six feet diameter, the space between the outer and inner cylinders being filled with gravel-pebbles; a bore-pipe, 20 inches diameter, and 45 feet long, is then driven to about ten feet into the chalk, and through this the boring is continued by an 18-inch auger, to the entire depth of the well. This well, and all the works connected with it, were completed at Christmas, 1846; and on the 1st of January, 1847, the whole of the works of the Mint, and the dwelling houses, were supplied with the water, which is raised in a six-inch main to a height of 50 feet above the surface, or 130 feet above the average level of the water in the well, and is delivered at the rate of 240 gallons per minute, by means of three pumps of 9-inch diameter, and 8-inch stroke, into a tank supported upon a building of brickwork. This tank is 100 feet long, 30 wide, and 5 deep; it contains, therefore, 15,000 cubic feet of water, or 93,750 imperial gallons. Two six-inch cast-iron mains, furnished with proper slide-valves, descend from this tank, one passing on either side of the Mint, so as conveniently to supply the whole of the establishment, the daily consumption of the water frequently exceeding 40,000 gallons; besides which a daily supply of 6,000 gallons is delivered, by means of a main laid from the Mint, across Tower-hill to the Tower, for the use of the inhabitants and the garrison, there being at present no serviceable wells in that fortress, and the water derived from the adjacent river being objectionable in point of cleanliness. The average height which the water attains in the shaft of the Mint well is 80 feet from the surface. After a day's pumping it is lowered, upon an average, 20 feet, but there it remains stationary, the flow of water from below maintaining the level, or in other words, delivering at the rate of about 240 gallons per minute. Before this well was completed, and before the boring into the chalk had been accomplished, the water derived from it contained 44 grains of dry saline matter in the imperial gallon. At present, the machinery being complete, and the well in full and daily use, the mean of several experiments in reference to the solid matter contained in the imperial gallon of the water, amounts to 37·5 grains. The substances contained in each gallon of the water are as follows:—

Sulphuric acid	7·44
Chlorine	6·31
Carbonic acid (after boiling)	5·84
Silica	0·50
Sodium (combined with chlorine)	4·22
Soda (combined with sulphuric and carbonic acids)	10·43
Lime	1·96
Magnesia	0·71
Organic matter, Phosphoric acid, Iron	Traces.

The water evaporated to one-fifth of its bulk, and filtered, had lost almost every trace of lime and of magnesia, so that it is probable that the greater part of these substances were held in the state of *carbonates*, by excess of carbonic acid. The carbonate of lime forms films during boiling, which subside, and appear under the microscope in the form of very minute acicular crystals. The crystalline deposit obtained by slowly evaporating the water after the precipitated carbonate of lime has been separated by filtra-

tion, exhibits under the microscope, three distinct forms—namely, cubes (of chloride of sodium), prisms, which lie distinct upon the other salts, and are efflorescent, sulphate of soda); and small aggregates of rhomboids intermixed with small spherical particles, like pin-heads (carbonate of soda). The residue of the evaporation of the water, after having been gradually raised to a dull red heat, acquired a grey tint, and exhaled a slight odour of burning azotized matter; and a piece of moistened turmeric paper held in the evolved vapour, was transitorily reddened.

Professor Brande had not been able to detect any potassa in this water; and only a slight indication of the presence of a phosphate, in the precipitate deposited by the water during boiling.

Upon the whole, he is inclined to regard the following as a tolerably correct statement of the proximate saline components of this water :—

	Grains in the Imperial gallon.
Chloride of sodium	10·53
Sulphate of soda	18·14
Carbonate of soda	8·63
Carbonate of lime	3·90
Carbonate of magnesia	1·50
Silica	0·50
Organic matter, Iron, Phosphoric acid	Traces.

The specific gravity of the water at 55° is 10007. Its gaseous contents he has not ascertained.

Mr. Brande concluded his paper by giving a short comparative table, of the relative quantity of solid matter contained in river and spring waters as have been carefully analysed. The wells which are termed *deep*, derive their water from the strata below the blue clay, and some of them penetrate into the chalk; those termed *shallow*, are supplied from the strata above the blue clay. This is the case with most of the common London wells, which, however, are often steined to a considerable depth in the clay, for the purpose of forming a reservoir.

		Solid matter in imp. gallon.
Thames at Greenwich		27·9
,, London		28·0
,, Westminster		24·6
,, Brentford		19·2
,, Twickenham		22·4
,, Teddington		17·4
Average of the Thames between Teddington and Greenwich		23·2
New River		19·2
Colne		21·8
Lea		23·7
Ravensbourne, at Deptford		20·0
Combe and Delafield's brewery, Long Acre;	deep well	56·8
Apothecaries' Hall, Blackfriars	,,	45·0
Notting-hill	,,	50·6
Royal Mint	,,	37·8
Hampstead Waterworks	,,	46·0
Berkeley-square	,,	60·0
Tilbury Fort	,,	75·0
Goding's brewery, Lambeth	,,	60·0
,, ,,	shallow well	110·0
Meux's brewery, Old-street	deep well	38·2
,, ,,	shallow well	110·0
Trafalgar-square fountains	deep well	68·9
Well in St. Paul's Churchyard		78·0
,, Bream's-buildings		115·0
,, St. Giles, Holborn		103·0
,, St. Martin's, Charing-cross		96·0
,, Postern-row, Tower		86·0
Artesian well at Grenelle, Paris		9·86

PROCEEDINGS OF SCIENTIFIC SOCIETIES.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Jan. 21.—Earl De Grey, President, in the Chair.

Earl De Grey informed the meeting that the Council, considering that much important information was contained in the Report and Evidence on Iron, equally applicable to architectural as to engineering purposes, had referred those volumes to the Committee on scientific experiments and investigations, for the purpose of examining and reporting thereon.

The President also communicated to the members, in reference to the Commission for the Exhibition of Works of Industry of all Nations, in 1851, that he had been officially applied to, doubtless with the sanction of her Majesty and Prince Albert, to be a member of that commission; but that he had been obliged to decline the honour on account of his health not permitting him to devote that attention, which would be required by the probably arduous duties of that commission. His lordship had no doubt, that the profession would be adequately represented by Mr. Barry, a fellow of the Institute, who had been appointed on the commission.

Mr. Bellamy, V.P., called the attention to an invention by Mr. Thomas Melling, by which the sashes of a window, instead of being lowered and raised, as at present, by lines, weights, and pulleys, acted by means of a rack, so that one sash served as a counterpoise to the other. Some observations were made thereon by the President and Members, and Mr. Melling was advised to render his useful invention still more practically available, by enabling only one sash to be opened at a time, instead of both at once, as requisite according to his present method.

A paper by Mr. Roberts, Fellow, was read, "*On the Arrangements and Construction of the Dwellings of the Labouring Classes,*" which will be given in full next month.

INSTITUTION OF CIVIL ENGINEERS.

Jan. 29.—William Cubitt, Esq., President, in the Chair.

The discussion was renewed on the Rev. J. C. Clutterbuck's paper "*On the Alterations and Depressions in the Chalk Water Level under London.*"

It was contended, that the water in the upper districts of the chalk accumulated in a proportion increasing with the distance from the river or vent, and fell off, in a corresponding ratio, during its periodical exhaustion, which usually took place between April and November of each year. This alternation of level, which in the upper districts exceeded fifty feet in perpendicular height, would be represented by a line from the lowest vent, rising at an angle to the highest point saturated with infiltrated water. This had been proved by constant observation on wells, at given periods, throughout a certain district; all the springs forming the river proceeded from that source. From these and other positions it was argued, that if water be discharged from a shaft in the chalk, by a power not capable of entirely exhausting it, the rapidity of the reduction of the level would gradually decrease, until it was exactly balanced by that of the supply. This would naturally produce a gradually-extending depression of the water in the strata for some distance around; and it was shown to have been the effect produced, by pumping from an experimental well in Bushey Meadows, in August and September, 1840.

It was urged, that the real question to be determined was, whether a supply of water for London could be obtained from the deep springs in the sand or chalk. Sections and diagrams were exhibited, to show, by the former, that the supposed basin under London, was not as had been shown by geologists; and by the latter, that from July, 1837, to December, 1849, there had been a gradual depression of full fifty feet in the water of the sand-springs under London; and in consequence of this serious action, several of the wells had become tidal in some localities, and the water was rendered saline.

The Railway Board.—The attention of the members was directed to a serious case of legislative interference, whereby the free exercise of the professional skill of the Institution was now unwarrantably trammelled, and the public service materially interfered with. The introduction of wrought iron instead of cast iron, into railway bridges, was a recent invention of great value, and of which the most celebrated examples were the Conway and Britannia bridges. The same executive authority which had pronounced the erection of these two bridges to be impracticable, had recently declared, that a railway bridge constructed on a similar principle, and of identical materials, was insufficient in strength, although it was much stronger, in proportion to its possible load, than either the Conway or the Britannia, and infinitely stronger than any of the cast iron girder bridges which had for years adequately performed the public service, and had been by the same authority pronounced to be perfectly safe. The public had thus already been for a month deprived of the use of an important line of railway, by the application of an antiquated formula to a modern invention. For these cogent reasons, it was considered that the members had a right to request the interference of the Council, on the behalf of the profession at large; and they were urged to take such steps as appeared desirable for allowing the free development of engineering talent; and in the words of the Report of a recent Royal Commission, removing from "a subject yet so novel and so rapidly progressive any legislative enactments, with respect to the forms and proportions of the iron structures" of railways, which could not fail to be "highly inexpedient."—This proposition was received with acclamation.

Mr. Evan Hopkins's great Geological Sections of the Three Branches of the Andes were exhibited in the library. They showed about 260 miles from west to east, from Choco to the River Meta, in the eastern flanks of the eastern branch of the Andes.

Feb. 5.—James Simpson, Esq., V.P., in the Chair.

The discussion was renewed on the Rev. Mr. Clutterbuck's paper, and was continued throughout the meeting, so that no original communication could be read.

It was contended, that the area of the chalk district, subject to infiltration, for the supply of the springs and streams uniting in the basin of the Colne, could not possibly exceed the original published estimate of 113½ square miles, and that the proportion of water filtrating through, for that purpose, was much less than had ever hitherto been estimated, inasmuch as records by Mr. Dickinson's gauge was to a much greater amount than those afforded by the gauges kept by other experimenters.

It was also contended, that the original position assumed in the paper, had not been weakened by the subsequent discussion; that the observations of the chemists had tended to confirm the statement of the probability of

an infiltration of water from the Thames. The practical conclusion to be drawn from the observations, recorded in the author's several papers were:—That the natural drainage and replenishment of the chalk stratum might be traced and accounted for, by observing the alternation of level, in various localities, and at different seasons. That any large quantity of water abstracted from the chalk stratum, at any given point, caused a depression of level around the point of such abstraction. That in the upper district any such abstraction of water would interfere with, and diminish the supply of, the streams, by which the drainage of the district was regulated; and lastly, that the depression of level under London, by pumping from Artesian wells, had proved that the rapidity of demand already exceeded that of the supply; and that any attempt to draw a large additional quantity for public use, would be attended with disastrous consequences.

It was suggested that, considering the great works of drainage and water supply which were in contemplation for the metropolis, and looking to the essential importance of having accurate and authentic geological information, in order that those great works might be executed on a sound and certain basis, that the geological survey now being carried on by government, in a remote district of North Wales, where no urgent need existed for early geological information, and where no new works of paramount importance were in progress, or in contemplation, should be transferred at once to the metropolitan districts, with a view to throw light on the real structure, mechanical and chemical, of the deep water-bearing strata, on which opinions so varying and so conflicting had been advanced.

An inquiry was made whether any steps had been taken by the council, in consequence of the statement submitted at the meeting of January 29th, urging the consideration of the manner in which the interests of the public at large, and of the profession were likely to be affected by the attitude recently assumed by the Railway Commission, in reference to the strength of the wrought-iron bridges used on railways.—It was stated that the council had not as yet taken any decided steps in the matter, but that a course had been suggested which, being followed, would most probably lead to satisfactory results. After this assurance the members expressed their confidence of the interests of the profession being in safe hands, and that every step would be taken for insuring their position and professional reputation.

The motion which had been prepared was therefore withdrawn; and the Chairman requested any communications on the subject to be made in writing to the Secretary, who would lay them before the council.

Feb. 12.—The first paper read was, "*An Account of the Cast-Iron Lighthouse Tower on Gibb's Hill, in the Bermudas.*" By Mr. P. Paterson.

The site chosen for this tower was in latitude 32° 14′ N., and longitude 64° 50′ W., being the southern part of the Bermudas, at which point they are most safely approached. It was at first determined to construct the tower with the materials found in the islands; but, after some progress had been made in quarrying and dressing the stone, it was ascertained to be of too friable a nature for the purpose, so that the Home Government instructed Mr. Alexander Gordon, M. Inst. C. E., to prepare a design for a cast-iron tower, similar to that which had been erected from his designs at Morant Point, Jamaica, and which had proved very successful. The form of this tower was that of a strong conoidal figure, 105 feet 9 inches in height, terminated at the top by an inverted conoidal figure, 4 feet high, in lieu of a capital; its extreme outside diameter was 24 feet, at the narrowest part 14 feet, and at the top 20 feet. The external shell was constructed of one hundred and thirty-five concentric cast-iron plates, having inside flanges, and varying in thickness from one inch at the base to about three quarters of an inch at the top. In the centre of the tower there was a hollow cast-iron column, eighteen inches in diameter in the inside, and of three-quarter inch metal, for supporting Fresnel's dioptric apparatus, and in which the revolving weight descended; it was also used, in the daytime, for raising and lowering of stores, and likewise contained the waste water-pipe. The lower part of the tower was filled with concrete, leaving a well, faced with brickwork, about eight feet in diameter, and twenty feet in depth, in the centre. Above this were the seven floors, the two lower ones being lined with brickwork, and used as store rooms; and the upper ones, lined with sheet iron, were used as living rooms for the light-keeper. The details were then given of the mode of constructing the floors, the windows, the staircases, and of attaching the lantern and light-room to the main structure; it was stated, that the light was visible from all points of the compass, excepting when obscured by the high land between Gibb's Hill and Castle Harbour, from the deck of a vessel at a distance of about twenty-seven miles, and possibly at a still greater distance. The structure occupied less than one year in its actual erection, the different parts having been landed about the end of November, 1844, the first plate being erected on Gibb's Hill on the 19th of December, 1844, and the last plate of the tower on the 9th of October, 1845. The whole cost of the structure, including the lantern and light apparatus, was stated to have been about 7,690*l.*, and the annual expense of maintaining it, about 450*l.*

The next paper read was, "*A Description of Sir George Cayley's Hot Air Engine.*" By Mr. W. W. Poingdestre.

After entering briefly into the theoretical considerations of the expansion of heated aëriform bodies, and detailing the attempts made by Lieut. Ericsson, for employing hot air instead of steam, as a prime mover, the author proceeded to state, that in 1837, Sir George Cayley, Bart., applied the products of combustion from close furnaces, so that they should act at once upon a piston in a cylinder, similar in every respect to that of a single-acting steam-engine. The engine consisted of a generator of heat, a working cylinder, and an air pump or blower, the air pump being half the size of the cylinder, and blowing air into, and through, a fire perfectly inclosed within the generator; the doors of the furnace were made perfectly air-tight as soon as the fire was well got up, the first impulse being given to the engine, by throwing a few jets of water upon the fire, which caused the air-pump to work immediately, and continued so for hours; the fire being replenished by stopping off the blast from the furnace, and opening the upper bonnet. After the air had passed through the fire, the gaseous products of combustion, generally at a temperature of 600° Fahrenheit, passed laterally through a chamber, used for separating them from any ashes or cinders, into the working cylinder before alluded to.

The difficulties attending this description of engine, were the liability of the working parts to be deranged, by the great sensible heat destroying the valves, pistons, and cylinders, and carbonising the lubricating oil. It was stated, that Mr. A. Gordon had made a successful experiment on the application of the heated products of combustion for propelling a boat, without the intervention of any machinery between the furnace and the water to be acted upon.

Feb. 19.—"*Description of the Iron Roof over the Railway Station, Lime Street, Liverpool.*" By Mr. Richard Turner.

The area covered was described as being 374 feet in length, and 153 ft. 6 in. in breadth, which was roofed over in one span. The roof consisted of a series of segmental girders or principals, fixed at intervals of 21 ft. 6 in. from centre to centre; these were supported, on one side, upon the walls of the offices, as far as they extended, and on the other upon cast-iron columns. From the end of the offices to the Viaduct over Hotham-street, a distance of 60 ft. 4 in., the principals were carried upon "box-beam" of wrought-iron. The principals were trussed vertically, by a series of radiating struts, which were made to act upon them, by straining the tie-rods and diagonal braces they were trussed laterally by purlins and by diagonal bracing, extending from the bottom of the radiating struts to the top of the corresponding strut in the adjoining girder; these braces were connected with linking-plates by a bar of the same scantling, and also with the purlins already referred to. The girders were thus firmly knitted together, and a rigid framework formed, upon which the covering of galvanised corrugated iron and glass was laid.

The whole construction was minutely described, and the appendix contained an account of the experiments for testing the strength of the principals. These were made at the works of Messrs. Turner and Son, Dublin, under the direction of Mr. Locke, the engineer of the railway, when some great improvements in the construction were introduced at his suggestion.

SOCIETY OF ARTS, LONDON.

Jan. 16.—William Tooke, Esq., F.R.S. V.P., in the Chair.

Mr. Walls read a paper "*On California, its History, Products, Climate, and Prospects; being the result of a recent visit to that place, by* Alexander Cross, Esq."

On the table were placed a few specimens of Californian gold, one of which was a large lump, weighing almost seven pounds, being the largest ever imported into England in a pure native state, and the property of Mr. Cross. A few specimens were also exhibited by Professor Tennant. Mr. Walls commenced by stating the extent of the country and its population, which, including the recent accessions, amounted at the present time to 90,000 people.

The country along the sea-coast is healthy; but fever is occasionally prevalent in the interior. After describing the situation of some of the principal stations, he proceeded to describe the valley of San Joachim, its extent and boundaries, every spot in which is stated to have produced gold of twenty carats fine. Several extracts from various sources were briefly alluded to in the paper; and from these the following matters were collected. Two young men had discovered gold in a place 500 miles north of San Joachim, and described their operations as having been attended with considerable success, having made in their best day 400 dollars, in their worst 150 dollars. As to the moral condition of the people, many of them became rich very quickly; but some expended their gains in profligacy and dissipation, so that the poorer class was fast increasing. The annual exports of gold from this country, according to Mr. Bryant's work on California, amounted to between 100 and 200,000,000 dollars. In many places linen washing was so expensive, that it was considered more economical to throw away old linen, and buy new. Emigrants, as they arrived, passed beyond into the country, and were doing well. The general health of the community was excellent. The disparity of the produce of labour in various parts sometimes occasioned considerable confusion. A new settler in about three weeks would succeed, by washing, to obtain an ounce of gold a-day; but the moment that he hears that at a distant place others were washing three, he immediately packs up his things, goes away, and is generally disappointed.

Mr. Tennant stated the specimen of gold exhibited by Mr. Walls was evidently a water-worn fragment. The gold is usually found in small grains, which are obtained by washing the alluvial soil. He also exhibited a specimen of gold which at the time he had purchased it (about two months before) was the finest specimen of pure native gold he had seen; it contained ninety-two per cent. of pure metal. A reason he had for purchasing the specimen was, because it had some of the alluvial soil attached to it; and in that soil he imagined that one or two small diamonds might be detected, and was most anxious to ascertain that fact, as he had stated to the Society last session, in a paper, that diamonds, and other precious stones, might be found in the gold districts of California; and that such gems are being thrown aside, although the refuse diamonds sold to the lapidary to be broken up are worth 50*l.* per ounce, while gold is not worth more than 3*l.* 15*s.* He had not, however, been able to discover any diamond; but, on examining the soil with the microscope, he had detected some small crystals of garnet, two grains of platinum, and several of quartz, &c. In looking over a quantity of other gold specimens, he had found quartz in great abundance, and it had evidently formed the original matrix of the gold. He next called attention to the fact, that gold is not generally found in the position in which it was originally deposited. Mr. Tennant urged on the attention of persons about to visit the gold districts the necessity of making themselves acquainted with the few simple rules which should guide them in their search for gold, and other minerals, and which were published in the Society's *Circular* last session.

Mr. Hopkins stated that there was nothing unusual in the gold deposits of California. The gold was found precisely under similar circumstances at the deposits of the Ural in Russia, and some other places. When the west tributaries of the Sacramento and the San Joachim have been washed, California will doubtless be brought to the ordinary level of large gold-producing countries. He was of opinion that metals were formed in the crystalline rocks in flakes, masses, crystals, arborescent, &c., according to the degree of the electro-chemical action, and that this action in the moist crystalline rocks *in situ* was as constant as the growth of vegetation. The surface products and the veins, he said, were formed on the same principle. He perfectly agreed with the remarks that were made, that those called geologists and others, who have been led to suppose that such products were the result of volcanic action, were totally wrong. In fact, true practical and useful geology was known only to a few persons who have studied amongst the great works of nature. Mr. Hopkins concluded by stating that gold is generally found in the debris of feruginous granites and porphyries, and that the quantity of gold to be obtained depends on the elementary composition of the granitic rocks, the complete saturation to induce chemical action, so as to cause a kind of efflorescence of the metals into all joints, vacuities, &c., and the oxidation and disintegration of the superficies. In fact, he said that the superficial decomposition of the moist and friable auriferous rocks were more or less constant, the degree of action and the accumulations at the foot of the mountains being dependent solely on mineral and physical conditions confined to no age of rocks nor to any particular zone; and that this electro-chemical agent was constantly providing inexhaustible stores of mineral wealth for successive generations. When the decomposed and friable surface is washed down to the ravines and plains, he said, the gold and other heavy ingredients, especially the black titaniferous iron (the usual companion of the precious metal), were deposited in pools and other places, presenting obstacles to their descent, and consequently those places have become enriched by concentration, the lighter particles being constantly washed away; and that this was the origin of the riches of the tributaries of the Sacramento.

ROYAL SCOTTISH SOCIETY OF ARTS.

Jan. 14.—Thomas Grainger, Esq., President, in the Chair.

The following communications were made:—

"*Verbal Statement on the relative value of Chlorine, Nitric Acid, Sulphurous Acid, and Ozone, as disinfectants; and on the best method of applying them to destruction of Contagious Matters.*" By George Wilson, M.D.

The author dwelt at length upon the relative value and best mode of applying, as disinfectants, the different substances mentioned in the title of his paper. A chief object of the communication was to draw attention to the alleged virtues of ozone as a purifier of the atmosphere, and to notice that, in defect of any other disinfectant, ozone might be generated in apartments, the air of which was vitiated by animal exhalations. The simplest process for this purpose would be the exposure of moist phosphorus to air; but an electrical machine or voltaic battery might also be used. The other point at which the author aimed was to show the unwise neglect of the sulphurous acid as a disinfectant, or rather antiseptic, which had been practised. It appears, according to Dr. Wilson, that in the wine countries this gas is employed to arrest the acidification of the weaker wines; that in the Manchester Dye Works it is found more efficacious than chlorine in destroying the offensive odour which attends the employment of cochineal; and that at paper mills it is employed with great success to prevent the putrefaction of the *scrolls* or clippings of the skin used in the manufacture of the paper size. The author accordingly strongly recommended sulphurous acid as a cheap and powerful deodoriser and disinfectant.

"*Remarks on the Philosophy of the Beautiful; and an Analysis of the principle of Proportion, as applicable to Architecture.*" (Part I.) By David Cousin, Esq., Architect.

The author combated the definition of the beautiful, as laid down by the late Mr. Alison and Lord Jeffrey, and held that beauty was recognised by the mind in particular *forms*, independently of any association connected with the object which it admires. This first part of the communication was entirely metaphysical, and cannot well be given in abstract. The author will read at next meeting, the second or practical part of his paper, showing how Mr. Hay's principles of proportion, determined by angles bearing harmonic ratios to each other, can be applied to architecture.

Jan. 29.—A paper was read by Mr. Meik, C.E., of Sunderland, upon "*A New Self Registering Tide Gauge, lately erected and now in operation at Sunderland Harbour,*" which was followed by a paper read by Mr. Henry Watson, of Newcastle, describing "*The Application of Prepared Gauze, by which means the Gauge is observable by Night as well as Day,*" a very important desideratum.

The merits of Mr. Meik's paper consisted in directing particular attention to the necessity of all ports and docks having conspicuous gauges for the guidance of vessels inward or outward bound, and of those gauges being of the most simple and intelligible description. Mr. Meik had prepared, and showed in juxta position, the present signals used at Leith, and those brought forward by him. For the information of our readers we may mention, that the signals used at Leith consist of a series of balls and flags which have to indicate to seamen the depth of water. The new gauge, at a single glance, shows the height of the tide in feet by a number in figures corresponding to the depth of water on the bar of a harbour or entrance to a dock. The little attention we often find paid by seamen to the preservation of their own lives, shows the great advantage of having figures that can be at once easily understood, without consulting books, and thereby incurring a loss of time, which in many cases results in the loss of valuable life and property. Mr. Meik proceeded to show that a gauge having the property of being easily understood by all as "soon as seen," had been erected by himself, in conjunction with Mr. Watson, for the Commissioners of the River Wear at Sunderland Harbour. He then read the following description, which was illustrated by drawings:—

A well, carefully boxed in, and of exactly similar depth to the water on the bar, is made below the building which contains the apparatus. Within this well, in an interior pipe or trunk, and rising and falling with the tide, works a float suspended by a copper wire cord, which is carried over a spiral cone fixed in an upper story of the building. By the simple arrangement of a wheel and pinion at the opposite end of the axle to which the cone is fixed, a web of wire gauze works on two rollers fixed at the upper and lower ends of the web. The lower roller is regulated by the movement of this wheel and pinion, the upper one by a balance weight attached to a copper wire cord, which also passes over another spiral cone, having at the extremity of its axle a second wheel and pinion similar to the first. As the float rises and falls with the tide, the wheels and pinions connected with the cones, over which the cords of the float and balance weight respectively pass, move the rollers on which the gauze web travels. On this web are painted in large figures the various depths from high to low water; and as the web works, two points upon it indicate the number of feet and half-feet on the bar at any hour of the tide.

The web and the figures on it can be made of any size, and to travel 4, 6, 8, 10, or any other proportion, to 1 of the float, by regulating the size of the wheels and pinions. By day the figures on the web are shown white on a black ground; by night they are brilliantly lighted up, the ground still remaining dark. A white transparent varnish is used for the figures, and an opaque black for the ground. The illumination by night is so steady and powerful, that the figures, if made large enough, and the apparatus fixed at a sufficient elevation, will be visible at a considerable distance at sea, and thus afford vessels the means of knowing the exact depth of water, at the mouth of any harbour, before entering it. This simple piece of mechanism is applicable to all places where the want of a correct and conspicuous gauge has been felt, not only in harbours and docks, but at *railway stations for signals*, and such like purposes. The apparatus used occupies so little space, that it can all be contained and worked in a column or pillar without any other building.

Mr. Watson read a paper describing more particularly the preparation of the wire gauze, and exhibited a neat specimen, which, although small, fully and clearly illustrated the novelty and utility of the application.

INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

Feb. 8—Lieut.-Col. Harry D. Jones, R.E., President, in the Chair.

The following papers were read:—

"*A Description of the Viaduct, near Quaker's Yard, Taff Vale Railway, South Wales.*" By Mr. S. Downing, Assistant Professor of Civil Engineering in Trinity College.

This viaduct was designed by Mr. Brunel, to carry the main line of the railway over the river Taff, at a point where, from the nature of the loca-

lity, such crossing was unavoidable. The total length of the viaduct was 470 feet, and the greatest height 105 feet, consisting of six semicircular arches, each 50 feet in span, resting on pillars, whose horizontal section was a regular octagon, 5 ft. 9½ in. in the side, giving 14 feet as their diameter. The whole structure was upon a curve of 1,320 feet radius, and at the point where it was determined to build, the axis of the river made an angle of 45° with the direction of the tangent to the curve. One of the chief merits of the design was the avoidance of the difficulties and expense of an oblique bridge with spiral courses in addition to those of curving; this was effected by the adoption of that form of pier above-mentioned. These pillars were surmounted by a capital of seven feet in height, the base of which, resting on the pier, was, of course, identical in plan with it; but in this height of seven feet was corbelled out on four of its faces to the extent of 1 ft. 3 in., changing the regular octagon into another, whose sides were 9 feet, and 3 ft. 7½ in. alternately. Two of the 9 feet sides were paralleled to the direction of the line of rails, and the other two formed the impost owspringing of the arch. The easiest way to have an idea of the form of the soffit of the arches, is by conceiving an ordinary semicircular arch of 50 ft. span and 14 ft. length, to have the arch quoins bevelled off to an extent of 2 ft. 6 in.; and to turn this arch a corresponding centre had to be made, being the ordinary laggings for the cylindrical part, and what were called by the workmen saddles for the conical faces. It will be evident to the practical engineer, that the proper bonding of all this work, and especially the arches, must be a matter of greatcare. A model, cut out of Caen stone, showing four courses of the arch, was produced, which clearly showed the alternate arrangement of the course. The arches being turned, and the spandrils filled up, there was a clear width of 14 feet from outside to outside of the up-stream and down-stream faces of the bridge, giving ultimately 11 ft. 6 in. in the clear between the parapet walls for carrying a single line of rails over; nor, indeed, does it seem possible with any advantage to extend the designso as to carry a double way, for thus the pier would be necessarily extended in diameter, or otherwise the chamfering of the soffit increased—both inadmissible, one from interfering with the water-way, and the other from the practical difficulty of bonding the work.

The quarries from whence the stone was obtained were in the immediate vicinity of the works. It was of the blue Pennant grit, called by Sir H. De la Beche, in the Government Geological Survey of this district, "The equivalent of the Pennant grit of the British coal measures;" and very truly characterised by him as being admirably adapted for engineering purposes. Its colour closely resembles that of the common building limestone of this neighbourhood. The lime used was the celebrated Aberthaw hydraulic limestone, not only in the foundations, but in all parts of the structure. The foundations on the north side, including one of the river piers, were on rock or indurated gravel; but on the south side the abutment, one land and one river pier, had to be sunk to a far greater depth than originally designed.

From the loftiness and peculiar design of this bridge, it was, during its construction, an object of great interest; and most persons who visited it expressed strong opinions unfavourable to its ultimate stability, most of which objections were very futile. The real difficulty in the construction was found to be the management of the spandril walls on the concave side, so as to gain the true uniform curvature at the stringcourse under the parapets, as on the concave side we had to gather out the courses of the spandrils about four inches, which, from the excellent quality of the stone, we were enabled to do.

It would seem necessary also to explain the reason for crossing the valley, and crossing it at such a height. Such structures seem rather to constitute the difficulty and expense of obtaining good gradients on cross-country lines, which necessarily intersect the rivers at elevations more or less considerable than that of a valley line, which, following the leading of one single stream, ought not, unless for cogent reasons, cross it at all. The consideration of the section of the river made it clear that no other alternative remained but this lofty and curved viaduct, intersecting the stream at the angle of 45°.

The paper was accompanied by a model of the river piers and cutwaters, with the centering and its supports, at a scale of one twenty-fourth, constructed under the author's direction by Mr. Keenan, and also by a diagram map, at two inches to the mile, showing the general features of the valley of the Taff—and another map, at six chains to the inch, showing the immediate locality of the viaduct, and the natural difficulties of the ground, with the added difficulty of carrying a line of rails through that district, from the great pre-occupation of the surface by the canal and its feeders, and the mineral tram-roads—and also a diagram section of the gradients of the line of railway, with a large isometrical drawing of two of the arches, showing by part section the arrangement of the spandril walls, the mode of closing them over as designed, and as carried out in the construction, with the form of the soffit, the capital, and pillar.

"*An Account of the Construction of the Midland Great-Western Railway of Ireland, over a Tract of Bogs, in the Counties of Meath and Westmeath.* By George W. Hemans, Engineer-in-Chief.

The railway from Dublin to Mullingar was projected, from motives of interest and policy, to follow the line, and occupy the banks, of the Royal Canal. The canal banks afforded some facilities for the construction of a railway, but it soon became evident that there were also disadvantages in following them too closely. The earthworks in constructing the canal, had been very heavy in character, with some of the deep cuttings through rock; and to relieve them as much as possible, the canal had been laid out to follow every sinuosity of the ground which offered a favourable level. The railway, as far as Mullingar, was also laid out along nearly the whole of these sinuosities; and there being great anxiety to open at least a portion of it at the earliest period, it was at once, on the passing of the bill, put into a contractor's hands for one-half the distance (as far as Enfield), and rapidly constructed on the canal banks. During the progress of these works, it was found to be desirable to avoid constructing the remainder of the line on a continued system of curves, which, although no longer, by well-informed engineers, considered a source of danger, are decidedly objectionable, as offering a resistance to the trains, causing greater friction, wear and tear, consumption of fuel, and loss of time besides lengthening the distance. In considering the plans for the second division of the line, between Enfield and Mullingar, the canal bank, which is a continued series of curves, was clearly to be avoided; but another difficulty presented itself on the straight line—the chord to these curves—it would have to traverse a long line of bogs, which, on careful examination with the boring-rod, proved to be from twenty-five to as much as seventy feet deep. Some of them were swell bogs of the softest pulpy nature, having gradually risen to a higher level than the surrounding country, and holding much water in suspension. After an extended examination of the subject, particularly in reference to drainage, it was at length apparent that one of the causes of the excess of water, and consequent want of solidity in these bogs, was the position of the canal embankment, traversing the edges of them for a great distance, and completely intercepting all drainage from them along the general fall of the country towards the river Deal. The following general plan was then at once resolved upon:—First, immediately to open full and sufficient new outlets for the escape of suspended water from the whole area; next, to form a system of drains all along and across the intended line; and finally, as a fixed principle, not to attempt either to excavate or embank the line, but to lay the rails on the natural level of the high bogs, trusting to drainage only to reduce the parts that were too high. With tolerable confidence in this plan, a Deviation Bill was passed through Parliament, and the straight line, traversing about eight miles of deep bog, was immediately commenced. An old wooden shoot, nine inches square, which was the sole outlet for the drainage of a district of about 1,600 square acres of wet bog, was the most ineffective point of the existing drainage, and was, therefore, the first to demand improvement. The banks and bottom of the canal at the place consist of clay artificially superposed on the cut away bog, lying on fine gravel of a very loose, treacherous description, being of a mixed sandy and marly nature. Having resolved on introducing a tunnel culvert, three feet diameter, under the canal at this spot, and that its invert should be six feet lower than the existing shoot, it became a matter of anxious consideration how to do this, in such bad ground, without interfering with the navigation of the canal, or running the risk of bursting a leak in the bottom. The canal level at this stage is twenty miles long, without a lock, and a breach would have been a serious affair.

Mr. Hemans here described very minutely the details of the execution of this very difficult work, which was altogether very successful, which secured the command for drainage of nearly four miles of the line of railway. The description of this important operation was farther illustrated by reference to several drawings prepared for the purpose.

While the foregoing work was in progress, a sum of about 1,000*l.* was being expended in the sinking a length of some miles of a river, and underpinning a culvert, ten feet wide, leading out of the next district of bogs.

This underpinning and building a new invert, at a level four feet below the old one, was also a work requiring great caution. The weight of the embankment and the canal overhead was very great; and here also a breach would have caused extensive damages. As soon as these outlets were ready, the drains in the bog were opened.

Mr. Hemans next proceeded to enter into a very clear explanation of the plan of operation pursued in the drainage of the surface of the bogs destined to receive the upper works of the railroad. He then described the nature of the soling finally decided upon and adopted, having given an account of the results of experiments on the several descriptions of soling which had been tested.

The construction of the upper works of the railroad were minutely detailed, and explanatory drawings were exhibited.

The mode of operation adopted in conveying this line of railway over the bogs of most unpromising aspect was eminently successful; and as the details of the works were so very different from the very expensive process generally adopted, and sometimes with but little success, the account was particularly interesting to the engineering world.

Mr. Hemans having made some observations on the cost of maintaining railways constructed through bogs, and also on a paper of great interest by the Messrs. Mullens, published in the second volume of the Transactions of the Institute of Civil Engineers of Ireland, concluded by reading a detailed estimate of the cost of these works, which clearly showed the possibility of constructing a double line of railway over deep bogs, when treated as described by him, at a cost not exceeding 6,000*l.* per mile, including all expenses.

NOTES OF THE MONTH.

On the Basement Bed of the London Clay.—At the Geological Society, on the 23d January, a paper was read on this subject by J. Prestwich, jun., Esq. The position of the plastic clay formation, above the chalk and below the London clay, has been long well established. It has, however, been recently held doubtful how far the distinction between the London and plastic clay series can be maintained,—and some even regard the latter as merely subordinate beds of the former. The object of the paper is to show, that the lower English tertiaries form several distinct subdivisions, each marked by different conditions,—indicating ancient hydrographical and palæontological changes of importance. For this purpose very numerous sections were described,—exhibiting the position and character of the lower part of the London clay. This deposit is a nearly homogeneous mass, several hundred feet thick, of tough clay, of a predominating brown colour. At its outcrop it inevitably rests on a conglomerate bed of round flint pebbles, mixed with yellow, green, or ferruginous sands in variable proportions,—which the author names the basement bed of the London clay. Except where denuded on the chalk downs, this bed extends uninterruptedly from the Isle of Wight to Woodbridge in Suffolk. The materials composing it seem to have been derived by denudation from the inferior tertiary strata. This bed contains 30 known and 9 or 10 still undescribed species of testacea. In the western part of the London district, the beds on which it rests contain no fossils; but at Woolwich, where it reposes on the fluviatile beds, six species of the estuary shells, found in the latter, also occur in the basement bed above, and four of them likewise in the freshwater series in the Isle of Wight. In the eastern district a few marine species are also introduced from the inferior tertiary beds. After deducting these, there remain 20 known species not found in the lower deposits, and constituting a distinct and well-marked group. Some of the species are very numerous and persistent through the whole range of the bed, but others die outwards towards the east; whence the author infers that the sea became shallower in that direction. In Essex and Suffolk, also, fossils are almost entirely wanting. From a table of the fossils it appeared, that the species were chiefly those of the London clay. It was, therefore, concluded that this bed forms a well-marked geological horizon, dividing this formation from the older eocene deposits.

The Screw Propeller.—On Monday, 11th February last, a question of considerable interest, in respect to steam navigation, was argued before the judicial committee, at the Privy Council Office, Whitehall, Lords Brougham, Campbell, and Langdale, Dr. Lushington, and Mr. Pemberton Leigh, being present. An application was made by Sir Frederick Thesiger, on behalf of the patentees of the screw propeller, for an extension of their patent, which expires in May next. The evidence went to prove, that no less than 30,000*l.* had been expended in building the Archimedes, and in defraying other weighty charges, to establish the screw-propulsion principle; and it further appeared, that although no less than 32 ships-of-war, and 100 mercantile steam-vessels had been constructed already upon this system, not more than two or three had paid for the patent license. These evasions had been occasioned by the conflicting claims of five different patentees; but, as these have now united in one association, it is expected that all who have adopted the use of the screw propeller will have to pay for their licenses. As the Admiralty are interested, either directly or collaterally, in this question, to the amount of about 25,000*l.*, Sir John Jervis, the Attorney-General, assisted by Mr. Crowder, Q.C., opposed the application for an extension of Mr. Frank Pettit Smith's patent; but, after examining Capts. Chappell and Crispin, R.N., and Messrs. Brunel and Galloway, engineers, their lordships decided on granting an extension of five years to Mr. Smith's patent upon certain conditions; and there is now, therefore, a fair prospect of that gentleman and his supporters recovering a portion, if not the whole, of the licensing moneys to which they are unquestionably entitled.

Brass Rudder.—A Philadelphia paper describes a large brass rudder, just completed in that city for the steam-ship Columbia, of New York, 25 feet long, 3 feet 8 inches wide in the blade, and weighing nearly 3000 lb.

Bishop's Rock Lighthouse.—We are sorry to have an unfavourable account of Mr. Walker's new lighthouse, described in Mr. Cubitt's address (see "Journal," p. 42), as being built on the Bishop's Rock, near the Scilly Islands, with six hollow cast-iron columns. The "West Briton" of February 15th says, "The massive pillars and apparatus erected during the last three summers at a vast expense, were entirely washed away on Tuesday night (the 5th). A St. Agnes pilot-cutter had since been out to the rock, and the pilots are of opinion, the rock is quite safe and sound. The pillars are broken off, some at the base, others at two, three, four, and five feet from the foundation, evidently proving that the pillars were not sufficiently strong; the sea was breaking over the rock at the time the pilot-cutter passed. It was consequently impossible to land."

Great Railroad Rope.—A rope for the Columbia Railroad, west of the Schuylkill river, Pa, has been manufactured for the inclined plane, by Messrs. J. Whetham and Son, Philadelphia. It required 14 tons of hemp for its construction, and it was 6000 feet long, 9 inches round, and weighed when completed, 25,000 lbs. This rope was made in less than 11 days, and the manufacturers have given a guarantee that the rope should transport 80,000 cars over the plane, which, we understand, is about the average service performed by two previous ropes furnished by their manufactory.

Brett's Electric Telegraph.—The concession signed by Louis Napoleon and the Minister of the Interior, M. Dufaure, granting to Messrs. J. Brett, Toche, and Co., the right to establish an electric telegraph line between France and England, by a submarine communication across the Channel, has been authorised. The Company propose to establish, by means of the electric telegraph, an instant communication between the two countries. The patentee guarantees that this telegraph shall, by the aid of a single wire and of two persons only (the one stationed in France and the other in England), be capable of printing in clear Roman type (on paper), 100 messages of 15 words each, including addresses and signatures, all ready for delivery in one hundred consecutive minutes.

Manufacture of Ice.—Sir J. F. W. Herschell, in reference to the system of making ice by the expansion of highly compressed air (previously reduced to the ordinary temperature), in a letter to the 'Athenæum', says:—An old steam-boiler buried some 20 or 30 feet underground in well rammed earth, and furnished with a condensing pump (worked aboveground), and one eduction pipe opening by a stop cock through a rose into water, would in all probability supply ice, 'ad libitum', for the use of a family in the country—the condensation being performed over night.

LIST OF NEW PATENTS.

GRANTED IN ENGLAND FROM JANUARY 24, TO FEBRUARY 23, 1850.

Six Months allowed for Enrolment, unless otherwise expressed.

John Dalton, of Hollingworth, Chester, calico-printer, for certain improvements in and applicable to, machinery or apparatus for bleaching, dyeing, printing, and finishing textile and other fabrics; and in the engraving of copper rollers, and other metallic bodies.—January 26.

Edwin Heycock, of Leeds, York, merchant, for certain improvements in the finishing and dressing of woollen cloths.—January 26.

Thomas Richardson, of Newcastle-upon-Tyne, chemist, for improvements in the manufacture of Epsom and other magnesian salts; also alum, and sulphate of ammonia.—January 26.

Winceslas le Baron de Traux de Wardin, of Liege, Belgium, for certain improvements in looms for weaving linen, woollen, and cotton cloths; and in machines for preparing the yarns for such cloths, before entering the loom; and in a machine for finishing grey and bleached linen cloths.—January 26.

Thomas Schofield, of Cambrook, Hulme, near Manchester, fustian dyer and finisher, and Henry Horabin, of Royton, near Oldham, fustian cutter, for improvements in machinery for cutting fustians and certain other fabrics, to produce a piled surface.—January 26.

Thomas Berger, of Hackney, gentleman, for improvements in the manufacture of starch.—January 26.

Richard Roberts, of Manchester, engineer, for improvements in the manufacture of certain textile fabrics, in machinery for weaving plain, figured, and terry or looped fabrics, and in machinery or apparatus for cutting velvets and other fabrics.—January 29.

Donald Beatson, of Green-street, Stepney, Middlesex, mariner, for certain improvements in instruments for taking, measuring, and computing angles.—January 29.

Ewald Rieps, of Finsbury-square, Middlesex, merchant, for improvements in the manufacture of steel.—January 29.

Joel Spiller, of Battersea, Surrey, engineer, for improvements in cleaning and grinding wheat.—January 29.

John Mason, of Rochdale, and Mark Smith, of Heywood, Lancaster, machine makers, for certain improvements in machinery or apparatus for preparing, spinning, and weaving cotton, and other textile materials; and also improvements in the method of preparing yarns or threads, and in the machinery or apparatus employed for such purposes.—January 29.

Francis Edward Colegrave, of Brighton, gentleman, for improvements in saddles; parts of which improvements are also applicable to the standing rigging and other furniture of ships or vessels, and to the connecting links or chains of railway carriages, and other purposes, where tension combined with a certain degree of elasticity are required.—January 29.

James Templeton of Glasgow, manufacturer, for certain improvements in manufacturing figured fabrics, principally designed for the production of carpeting.—January 29.

William Edward Newton, of Chancery-lane, civil-engineer, for improvements in machinery or apparatus for making hat bodies, and other similar articles. (A communication.)—January 29.

Thomas Berry, of Salford, Lancaster, silk, worsted, and piece dyer and finisher, and Nathan Ramsden, of Salford, in the said county, calenderman and finisher, for certain improvements in the construction of machines for glazing, embossing, and finishing woven fabrics and paper.—January 31.

Albert Dummler, of Mark-lane, London, for improvements in obtaining fibres from textile plants.—January 31.

Etienne Joseph Hanon Valck, Belgium, miller, for improvements in grinding.—January 31.

Edward Highton, of Clarence-villa, Regent's-park, Middlesex, engineer, for improvements in electric telegraphs, and in making telegraphic communications.—February 7.

Charles Atherton, member of the Institution of Civil Engineers of London, for an improved apparatus or machinery for regulating the admission of steam to the cylinders of steam-engines.—February 7.

Thomas Auchterlonie, of Glasgow, North Britain, manufacturer and calico printer, for improvements in the production of ornamental fabrics.—February 7.

Edward Ormerod, of Manchester, mechanical engineer, and Joseph Shepherd, of Chorlton-upon-Medlock, in the same county, mechanical engineer, for improvements in, or applicable to, apparatus for changing the position of carriages on railways.—February 7.

Louis Jean Jacques, Viscount de Serionne, of Paris, gentleman, for certain improvements in the manufacture of buttons, and in the apparatus and machinery used therein.—February 9.

Bryan Donkin, the younger, of Bermondsey, Surrey, civil engineer, and Bernard William Farey, of Old Kent-road, Surrey, civil engineer, for improvements in steam-engines; and an improved fluid meter.—February 9.

Read Holliday, of Huddersfield, for improvements in lamps.—Feb. 11.

William Blinkhorn, of Sutton, Lancaster, glass manufacturer, for certain improvements in machinery, to be used in the manufacture of glass.—February 11.

James Webster, of Leicester, engineer, for improvements in the production of gas for the purposes of light.—February 12.

John Mackintosh, of Berners-street, Oxford-street, civil engineer, for improvements in obtaining power in the floating of bodies; and in conveying fluids.—Feb. 12.

Thomas Whiffen, of Pig's-quay, Bridewell Precinct, accountant, for improvements in machinery for registering the delivery of goods.—February 21.

John Steven Woolrich, of Wednesbury, Stafford, chemist, John James Russell, of Handsworth, in the same county, and Thomas Henry Russell, of Wednesbury aforesaid, patent tube manufacturers, for improvements in obtaining cadmium and other metals and products from ores or matters containing them.—February 21.

Alfred Vincent Newton, of Chancery-lane, Middlesex, mechanical draughtsman, for improvements in separating and assorting solid materials or substances of different specific gravities. (A communication.)—February 21.

John Slack, of Manchester, Lancaster, manager, for certain improvements in the manufacture of textile goods or fabrics, and in certain machinery or apparatus connected therewith.—February 21.

Alexander Hediard, of Paris, France, gentleman, for certain improvements in propelling.—February 21.

George Holworthy Palmer, of Westbourne-villas, Harrow-road, Middlesex, civil engineer, and Joshua Horton, of the Ætna steam-engine boiler and gasometer manufactory, Smethwick, near Birmingham, Stafford, for improvements in the arrangement and construction of gas-holders.—February 21.

William Cormack, of King street, Dunstan-road, Haggerston, Middlesex, chemist, for improvements in purifying gas; also applicable in obtaining or separating certain products or materials from gas-water, and other similar fluids.—February 21.

William Mayo, of the firm of Mayo and Warmington, Silver-street, Wood-street, Cheapside, manufacturers of mineral aerated waters, for improvements in connecting tubes and pipes, and other surfaces of glass and earthenware.—February 21.

John Scoffern, of Essex-street, Middlesex, M.D., for improvements in the manufacture and refining of sugar, and in the treatment and use of matters obtained in such manufacture, and in the construction of valves used in such and other manufactures.—February 21.

LECTURES ON ARCHITECTURE,

By Samuel Clegg, Jun., Esq.;

Delivered at the College for General Practical Science, Putney, Surrey.

(President, His Grace the Duke of Buccleuch, K.G.)

Lecture IV.—Pelasgic remains in Greece, Italy, Asia Minor. Architecture of the Jews.

It is singular, that in those countries where Art advanced the most rapidly towards perfection, we should be able to ascertain the least respecting its origin and progress. The history of the earliest races inhabiting these favoured regions is so enveloped in myth and mystery, that even the fact of their having really existed might be doubted, did not so many giant ruins remain to attest the work of their hands. These remains, whether found in Asia Minor, Greece, or Italy, are generally known by the name of "Cyclopean" or "Pelasgic." It is not necessary to our purpose, to enter upon the complicated question as to the what, or whence, of these great builders of the olden time. This is not the place to determine whether the Cyclopes (believed to be one-eyed, from the circumstance of their wearing helmets with one aperture) were a tribe of Celtæ from Asia, or from Sicily, or whether their name was applied indiscriminately to any unknown race of great strength. It is enough to know, that among the ancients the name "Cyclopean" was given to any work requiring more than ordinary power. As for the Pelasgians, the learned Niebuhr declares their very name cannot be pronounced by the historian, without a feeling of distrust, on account of the want of evidence as to their origin and the derivation of their name, and the many conflicting opinions concerning them. Wherever their native country may have been, they certainly soon spread themselves over a wide extent of territory; for we find these mysterious wanderers preceding the Hellenists in the Peloponnesus, and, together with the Etruscans, Umbrians, and Ænotrians, sharing the Tyrrhenian name in Italy.

For the sake of classification, it is convenient to call the walls formed by rough blocks of unhewn stone, piled rather than fitted on to each other, by the name of "Cyclopean;" while the walls constructed with accurately-fitted, uncemented polygonal or quadrangular blocks may be distinguished as "Pelasgian." The first kind, or Cyclopean masonry, which may have been adopted by any race of builders in a rude age, was composed of blocks of great size, irregularly shaped, and rough as they were taken from the quarry, the interstices being filled-in with small stones. The second kind, or Pelasgian, belongs to a more advanced state of society. The use of polygonal blocks, no doubt, originated in the natural cleavage of the stone. The blocks were carefully dressed, and frequently even polished, to insure their being accurately fitted. Quadrangular stones were, of course, substituted when the cleavage assumed that form; but they were not hewn to a size, nor laid in regular courses—a style of masonry belonging to a still more civilised age, and no doubt originating with a brick-making people. Remains of polygonal masonry, of beautiful workmanship, are to be found at Pterium or Tavium, in Asia Minor, at Cosa in Italy, and in various other places in both countries. Mr. Dennis speaks of the polygonal blocks forming the walls of Cosa as being so exquisitely fitted, "that the joints are mere lines," and says that not even "a penknife" could be inserted between them, the outside surface being as smooth as a "billiard-table."

According to Strabo, the position of cities may be cited as an accurate test of civilisation and social security: judging by this rule, the Pelasgians must have been a wild race, for they chose the steep rocks rising abruptly from the plain, on which to found their eyrie; and here they built those huge walls,

> "Piled by the hands of giants,
> For god-like kings of old,"

—walls which have defied the power of time, as once they defied human adversaries.

In most of these ancient fortifications, the walls were guarded by square towers at intervals, where sentinels were posted to give notice of impending danger. Alarm was given by means of fire; hence they were called torch or beacon towers. The gates were in all cases defended by towers, even where the walls were plain. Gates seem to have been considered as necessary evils, or were as few in number as possible; many of these old cities only possessing two. The multiplication of gateways was considered as the greatest proof of the strength and valour of the community; and thus cities were celebrated by the number of their gates, like Thebes. The gates were small in size, and were at first made of wood, and secured by wooden bars; as the arts progressed, the wooden doors were strengthened by plates of brass or iron, and had bars of metal. No city, defended by these Pelasgian fortifications, could be overcome by the engines then in use, and were never taken except by stratagem or treachery: thus Troy owed its fall to the wooden horse, and the Bœotian Thebes was voluntarily abandoned by its citizens, under a warning from the gods.

It is well for human progress that the first settlers had rendered their rocky fortresses thus impregnable, that those who had begun to acquire the arts of civilised life should be able to protect their strongholds against the ruder and poorer; and should retain their position until political organisation and discipline was sufficiently matured in rival states to allow them, in their turn, to achieve and maintain the superiority. In course of time, as the population became too dense to occupy the summit of the hill, they spread themselves over the plain below; the original city was then distinguished by the name of "Acropolis," or upper town, and not only formed the citadel, but was considered as consecrated ground—where the shrine of the tutelary deity was erected, and the treasures and archives deposited. At first, probably, the lower town consisted only of wooden huts, which are supposed to have furnished the model for future erections in stone; such huts as form the dwellings of the peasantry of Asia Minor at the present day.

The Homeric poems present us with a picture of some degree of civilisation, as having existed in Greece at that early time—walled towns, fixed abodes, individual and hereditary landed property, carefully-cultivated vineyards, altars to the gods, and palaces for the chiefs. In the earliest ages we have no mention of temples, or statues of the divinities; but the sacrifices appear to have been offered on an altar in the court of the palace, where the king or chief officiated. In the time of Homer, the shrine at Delphi was merely a small wooden structure, covered in with laurel branches. The little we know of the palaces of the ancient Greek kings is derived from the pages of Homer. The following description of the house of Alcinoüs gives an idea of splendour and luxury, though displayed in somewhat barbaric taste.

> "The walls were massy brass: the cornice high
> Blue metals crowned, in colour of the sky;
> Rich plates of gold, the folding doors incase;
> The pillars silver, on a brazen base;
> Silver the lintels deep projecting o'er,
> And gold, the ringlets that surround the door.
> Two rows of stately dogs, on either hand,
> In sculptured gold, and labour'd silver stand.
> These Vulcan formed with art divine, to wait
> Immortal guardians at Alcinoüs' gate.
> * * * * * *
> Fair thrones within from space to space were rais'd,
> Where various carpets with embroidery blazed,
> The work of matrons."
>
> —Od: Pope's Homer.

We are reminded by the rows of guardian dogs, at the door of the house of Alcinoüs, of the dromos of sphinxes leading to the palace of the Egyptian kings. From the Homeric poems we may also obtain a glimpse of the interior arrangement of these ancient dwellings, as the bard no doubt described the palace of Ulysses after the general plan of houses of that age. They appear to have been built in three divisions: first, the aula, or open court, surrounded by apartments. This court had a peristyle, or colonnade, round it, covered with a pent, or roof; beneath this was spread the couches for the men. Telemachus and Pisistratus are described as sleeping beneath this colonnade, in the palace of Nestor. In the centre of the aula, stood the altar; in the palace of Ulysses it was dedicated to Jupiter.

> ———— "With timorous awe,
> From the dire scene th' exempted two withdraw;
> Scarce sure of life, look round, and trembling move
> To the bright altar of protecting Jove."
>
> —Odyssey.

The aula was entered by gates from the street; and opposite the entrance was a portico or vestibule, leading to the second division, which included the great banqueting-hall; this appears to have been a splendid and spacious apartment, the roof supported by columns, and the walls hung with tapestry. When Minerva visits Telemachus, the suitors are sitting on hides or skins, in the vestibule, feasting and playing at chess. Telemachus leads Minerva into the great hall, and receiving the spear from her hand, places it against a column. We are not acquainted with the third division, the gynæceum, or women's apartments; it is evident that they inhabited an upper story, for the females are invariably described as descending when they make their appearance in the other part of the house. The gynæceum seems to have communicated with

the banqueting-hall by folding doors: thus, speaking of Penelope—

> "Touch'd at the dreadful story, she descends;
> Her hasty steps a damsel train attends.
> Full where the dome its shining valves expands,
> Sudden before the rival powers she stands."
>
> —Odyssey.

The aula was paved with marble; but the floors of the inner apartments were of polished wood, as were also the imposts of the gateway. The chamber where the treasures were kept is described as having a floor of polished oak, and the roof supported by columns, from one of which Penelope took down the bow of Ulysses. Attached to the house was a base court, which contained the stables, granaries, and other farm buildings; in this court was a circular structure, with a conical dome, called a tholus; it had a wooden pillar in the centre, but for what use this building was designed is uncertain—it may have been a store-room, or perhaps a threshing-floor.

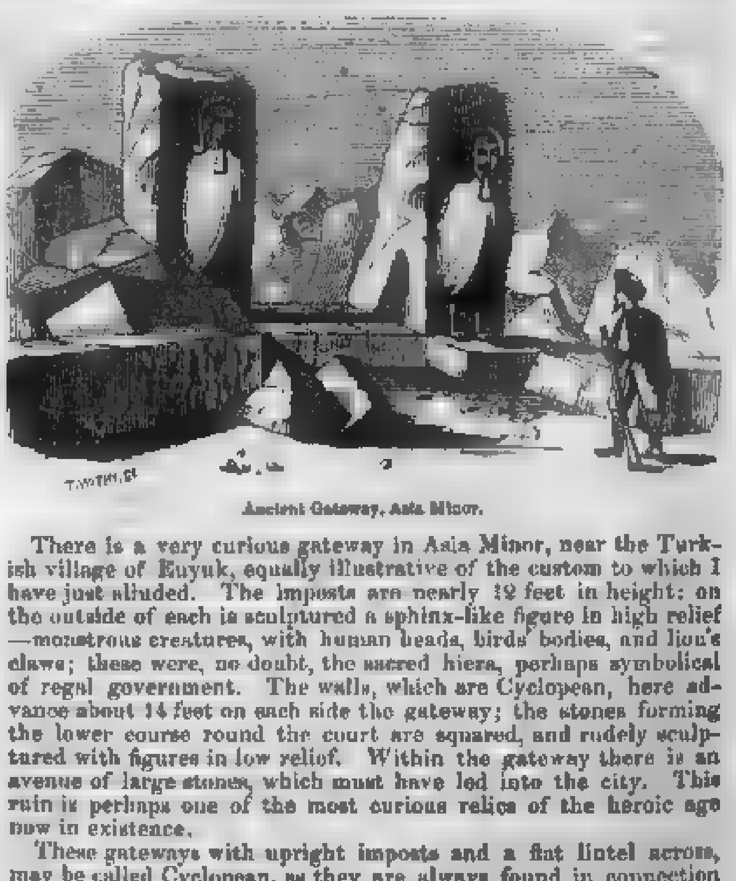
Egyptian influence has been suggested by the tapering form of the doors and windows in Greek architecture; but it must be remembered, that while the exterior wall of Egyptian buildings assumed a pyramidal form, the apertures were always vertical; in the Greek, on the contrary, the doors and windows only sloped inwards, the exterior wall being invariably vertical.

According to Pausanias, Lycosura in Arcadia was the most ancient city in Greece; a few Cyclopean walls only remain.—Tiryns in Argos follows next in date, and is said to have been founded 1710 B.C., upwards of 900 years before the first recorded Olympiad. Both Homer and Hesiod mention the well-built walls of Tiryns: those of the Acropolis are formed of enormous blocks of unhewn stones; the external wall varies in thickness from 19 ft. 9 in. to 25 ft. 3 in.; many of the blocks of which it is constructed are 10 feet in length, and some as much as 13 feet in length by 4 ft. 4 in. in thickness; their breadth is from 3 feet to 7 ft. 6 in. The gallery of Tiryns is the most ancient vault in Greece; the doorways are formed by stones placed obliquely, and meeting at the summit, thus forming a kind of pointed arch: this form is met with wherever Cyclopean remains exist.

We know nothing of the inhabitants of this city, except from an anecdote Athenæus has left us. It seems they were a wonderfully frivolous and light-headed people, making a jest of the most serious matters, and always ready for a laugh; at last this propensity became beyond a joke, and they applied to the oracle at Delphi for some means by which to get quit of their superabundant hilarity. The answer vouchsafed was, that they were gravely to sacrifice a bull to the god Poseidon, and with equal gravity to cast it into the sea. On an appointed day, the inhabitants of Tiryns assembled to witness the much to be desired consummation, and behaved with becoming decorum; till an unlucky youth, repelled in his endeavour to force his way through the crowd, exclaimed, "What! are you afraid I should swallow your bull?" This idea so tickled the fancy of the giddy-pated multitude, that they burst into a loud laugh, the sacrifice was interrupted, and they thenceforward resigned themselves to an inevitable destiny.

The most perfect and interesting Pelasgic ruin in Greece is the ancient Mycenæ, in Argolis, the capital city of the unfortunate race of Atreus. Its early kings were so wealthy, as to gain for it the title of the "Golden Mycenæ." The citadel is an oblong, nearly 1000 feet in length, and is entered by two gates, on opposite sides. There were towers on each side the gates, but none round the walls. The custom of consecrating gates, by placing over or upon them sacred images, has existed in every period of history: the Gate of the Lions (so called), at Mycenæ, is an example of this time-honoured usage. As the citadel was consecrated ground, the principal entrance-gate was likewise holy; the image placed above was the symbol of the tutelary deity, the hieron before which the people worshipped: as in Ezekiel xlvi. 3., "Likewise the people of the land shall worship at the door of this gate, before the Lord, in the Sabbaths and in the new moons;" and again, in Psalms, lxxxvii. 2, "The Lord loveth the gates of Zion more than all the dwellings of Jacob." The people of Mycenæ and Argos were worshippers of Apollo, as the Sun-god, the same divinity as the Indian Bacchus.* The animals sculptured above the gateway are evidently intended for panthers, not lions: the panther was consecrated to the Indian Bacchus; the orb and pillar, placed between the panthers, were also dedicated to Apollo, or sun worship.

Not only were religious ceremonies performed, but markets, and courts of judicature, were held before the holy gate; for this purpose, a paved court or open space was necessary, where the kings or judges could hold their sittings on solemn occasions. This custom is alluded to in many passages of holy writ, as in Deuteronomy xvi. 18: "Judges and officers shalt thou make thee in all thy gates, which the Lord thy God giveth thee, throughout thy tribes; and they shall judge the people with just judgment." In 1st Kings, xxii. 10: "And the king of Israel, and Jehoshaphat the king of Judah, sat each on his throne, having put on their robes, in a void place in the entrance of the gate of Samaria, and all the prophets prophesied before them." In the Book of Proverbs, i. 21: "She crieth in the chief place of concourse, in the openings of the gates;" and in Prov. xxxi. 23: "Her husband is known in the gates, when he sitteth among the elders of the land." At Mycenæ, the walls of the citadel project in parallel lines, so as to form an area, or oblong court, before the gateway. The Lions' Gate is now nearly filled up with earth and rubbish, so that its height cannot be ascertained; it is 9½ feet in breadth; the stone forming the lintel is 15 feet in length, 6 ft. 8 in. in breadth, and 4 feet in height. The panthers, with the orb and pillar, are sculptured on a piece of green basalt, of triangular form, which is let in above the lintel: the opposite gateway is constructed in a similar manner, but the triangular stone above the lintel is plain, not sculptured. In some instances there would seem to have been an outer gate, as David is described as sitting *between* the gates, waiting to hear the result of the battle between Joab and Absalom.



Ancient Gateway, Asia Minor.

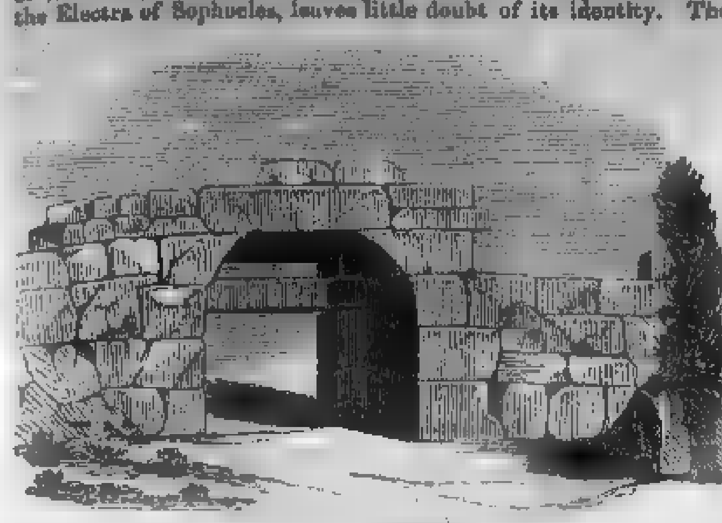
There is a very curious gateway in Asia Minor, near the Turkish village of Euyuk, equally illustrative of the custom to which I have just alluded. The imposts are nearly 12 feet in height: on the outside of each is sculptured a sphinx-like figure in high relief—monstrous creatures, with human heads, birds' bodies, and lion's claws; these were, no doubt, the sacred hiera, perhaps symbolical of regal government. The walls, which are Cyclopean, here advance about 14 feet on each side the gateway; the stones forming the lower course round the court are squared, and rudely sculptured with figures in low relief. Within the gateway there is an avenue of large stones, which must have led into the city. This ruin is perhaps one of the most curious relics of the heroic age now in existence.

These gateways with upright imposts and a flat lintel across, may be called Cyclopean, as they are always found in connection with rude unhewn masonry; when the span was too great for a block of stone, a wooden beam was placed across as a lintel.—Pelasgic gateways are generally rude arches, formed by the courses of stones projecting one over another, capped by a flat stone at the summit: the accompanying drawing is an illustration of this style of construction—the Gateway of Ancient Ephesus, which, it will be observed, approaches very closely to the perfect arch in outline.

Immediately without the walls of Mycenæ, rises a mound or tumulus, and within this is the tholus or vaulted chamber, sometimes called the Treasury of Atreus, but now generally known as the Tomb of Agamemnon. The treasury of Atreus is mentioned as a brazen chamber; but this vault could scarcely have been so described, even if the walls had been lined with metal plates, as has been conjectured from the nails in the wall. Nor is it probable that a treasury, containing the wealth of the state, would be situated without the walls of the citadel; besides, the very form of the tumulus seems to announce a sepulchre; and the comparison

* Here again we meet with a remnant of the old Mithraic worship.

of the situation with the allusions to the tomb of Agamemnon, in the Electra of Sophocles, leaves little doubt of its identity. The



Gateway of Ancient Ephesus.

entrance to the vault is a doorway of elaborate design, sculptured in green basalt; a restoration from the fragments remaining is published in the supplementary volume of Stuart and Revett's 'Antiquities of Athens.' The doorway was originally approached by steps, but the earth has now accumulated above the threshold. It differs widely in design and detail from the Greek of after ages: the door or gate was brazen; the columns are decidedly Asiatic in character; the capitals closely resemble the Egyptian, though the bases approach the Greek in graceful outline; the peculiar scroll forming the principal decoration is quite distinct from the Greek meander, but is met with in some of the Egyptian tombs; the vandyke may have been suggested by a section of the palm. On the triangular tablet the panthers with the orb and pillar are carved in relief. The vaulted chamber is circular, 48 feet in diameter; the present height is 49 feet, but it must originally have been much higher, as the ground has been raised by the earth and stones falling in. This vault is formed in the usual Pelasgic manner, by the projecting courses of stones, afterwards hollowed out, and indicates no knowledge of the principle of the arch. The stone used is the hard breccia, found upon the spot: 30 regular courses are exposed to view; they are uncemented, but united with the greatest precision. The wall of the building is 18 feet in thickness; consequently, there is a passage 18 feet in length between the outer and inner door. The stones forming the roof of this passage are of enormous size: the lintel of the inner doorway is composed of two blocks, the largest 27 feet in length, 17 in breadth, and 3 ft. 9 in. in thickness, the weight being about 133 tons—a block only inferior in size to those of Karnac and Baalbec. A small square chamber opens from the larger apartment.

A sepulchre of somewhat similar construction has been discovered on the site of the ancient Caere, formerly the still more ancient Agylla, one of the earliest Pelasgic settlements in Italy. This tomb (known by the name of its two discoverers, Regulini-Galassi) is entered by a Pelasgic archway: the chambers are oblong, instead of circular, but vaulted in the manner already described. This sepulchre was opened for the first time only a few years ago: the funeral beds stood in their original places, with the armour and jewels upon them, though their occupants had long crumbled into dust; shields, spears, and other weapons, as well as vases and pateræ of various forms, were suspended from the walls by nails. As we know that the traditional rites of burial were religiously observed by the early races, we may conclude that the nails in the wall of Agamemnon's tomb were for the purpose of attaching sepulchral furniture, rather than brazen plates.—Mycenæ was destroyed by the Argives, 500 B.C.

At Orchomenos, in Bœotia, are other interesting Pelasgic remains; amongst which may be mentioned the Treasury of Minyas, a vaulted chamber of still larger proportions than the Tomb of Agamemnon. It was once covered by a dome, but the upper part has now fallen in. This building was considered by the ancients as one of the wonders of the world, equally with the pyramids of Egypt and the walls of Tiryns, and is said to have been the work of the celebrated Agamedes and Trophonius.

In Bœotia are the remains of the greatest, as well as the most ancient engineering work achieved by the Greeks. Between the Kopaic lake and the sea, is a mountain of calcareous limestone, called Mount Ptoön: the river Kesephus is formed by the overflowing waters of the lake finding or forcing their way through the fissures of the mountain. These did not, however, afford a sufficient channel, and frequent inundations were the consequence. To remedy this evil, artificial tunnels were cut through the whole breadth of Mount Ptoön. The north-eastern tunnel is rather more than 3¼ miles in length, with about twenty vertical shafts let down into it along the whole distance. The shafts are now choked up, but the apertures are yet visible, and are about 4 feet square; the deepest is supposed by Forchhammer to be about 150 feet. These shafts are thought to have been for the purpose of allowing a greater number of workmen to be employed at the same time, so as to carry on the work more quickly—just for the same reason that we sink shafts at present. It is said that these tunnels were cleared out and repaired by Crates of Chalcis, who, according to Strabo, presented a report to his employer, Alexander the Great, stating that the remains of several ancient cities had been brought to light, formerly submerged by the overflowing of the Kopaic lake.

There are many more Cyclopean and Pelasgic remains in Greece and the neighbouring islands, but they merely consist of huge walls, with here and there a gateway more or less perfect.

Asia Minor, that beautiful peninsula thrown (as Laborde observes) like a bridge between Asia and Europe, notwithstanding the genius of its people, never formed a great kingdom: its destiny was to become a battle-field, where a succession of heroes struggled for the dominion of the world. The names of Crœsus, Cyrus, Xerxes, Xenophon, Alexander the Great, Mithradates, hallow every spot of ground with a thousand historical associations, even before the foundation of the Christian churches gave a still more vivid interest to the land. It was anciently divided into several small kingdoms, that sometimes successfully struggled against, and sometimes succumbed, before the power of Persia. After the check given to the Persian dominion by the defeat of Xerxes, the numerous cities on the coast of Ionia, Ætolia, and Caria, founded by emigrants or exiles from Greece, increased in power and importance, and rivalled the mother country in art, in science, and in literature. After the battles of the Granicus and Issus, won by the great Alexander, Asia Minor was united to the Macedonian kingdom, but again dissevered at his death, when his successors, Antigonus, Eumenes, and Lysimachus, obtained possession of different provinces. In the year 133 B.C., Attalus Philopater, king of Pergamus, bequeathed his kingdom to Rome; but the peninsula was not completely subjected to this mighty empire till after the defeat of Mithradates, the great king of Pontus (63 B.C.)

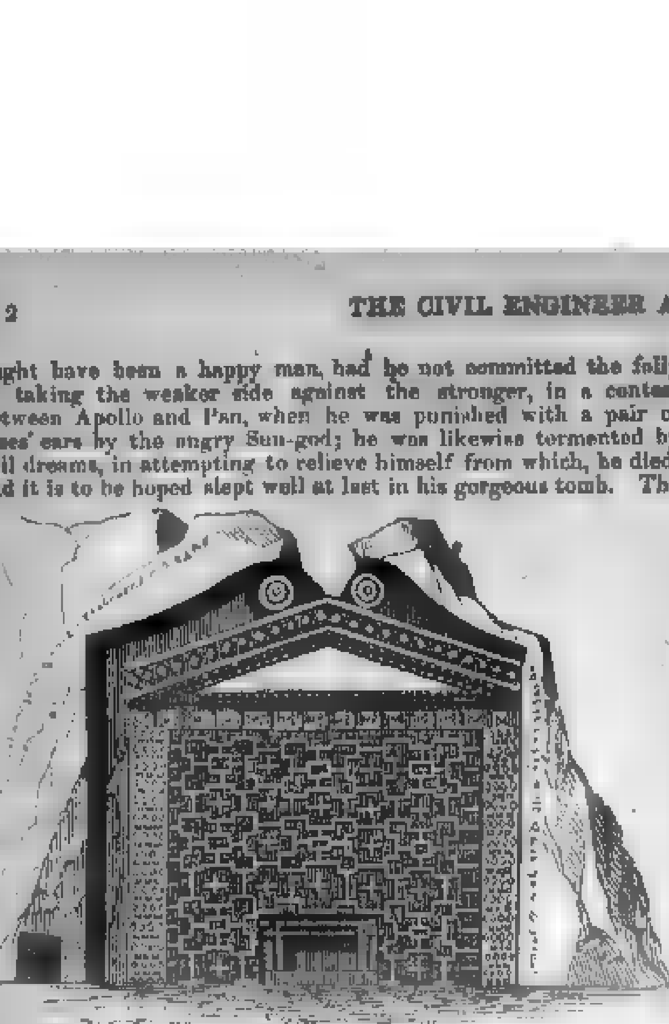
In each of the small kingdoms of Asia Minor, a distinct style of architecture seems to have prevailed; though of this variety, the tombs alone remain to bear witness. Truly, as Shelley says,

> ———————— "Dead men
> Hang their mute thoughts on the mute walls around;"

and the abodes of the dead frequently bear record of a race whose living habitations have long disappeared. In each little kingdom, the ancient mode of sepulture seems to have been religiously adhered to, whether under Greeks or Romans, to as late a date as the Christian era. From the innumerable excavations in the rocky districts of Asia Minor, it has been supposed that they were not only used for sepulchral purposes, but had in still more ancient times been the retreat of some Troglodytic or cave-dwelling tribe, like the ancient Edom. It is possible that the rocks may originally have afforded shelter to such a race, and their caves have been converted into sepulchres by subsequent inhabitants: but this is all conjecture. In Cappadocia, Phrygia, and other provinces, many chains of rocks are completely honeycombed with excavations—perforated with thousands of chambers, niches, and passages.

Phrygia, being an inland kingdom, was further removed from the influence of the Greek colonies, and approaches more nearly to the Persian in architectural style. The characteristic of Phrygian tombs is the sculptured façade chiselled on the surface of the rock; some are rude and simple, others elaborately decorated. The Tomb of Midas is one of the most richly ornamented. This sepulchre takes us back to the fabulous ages: we at once remember Midas, king of Phrygia, son of Gorgias, that miser of the olden time, who prayed that whatever he touched might be turned into gold; and when his prayer was granted, would have starved to death in the midst of his riches (every morsel being transmuted as it touched his hungry lips), had it not been for the tender mercy of Bacchus, who ordered him to bathe in the river Pactolus, when its sands were changed into gold, and Midas was relieved from his fatal gift. Thus cleansed and purified from his golden fever, he

might have been a happy man, had he not committed the folly of taking the weaker side against the stronger, in a contest between Apollo and Pan, when he was punished with a pair of asses' ears by the angry Sun-god; he was likewise tormented by evil dreams, in attempting to relieve himself from which, he died, and it is to be hoped slept well at last in his gorgeous tomb. The



Tomb of Midas, King of Phrygia

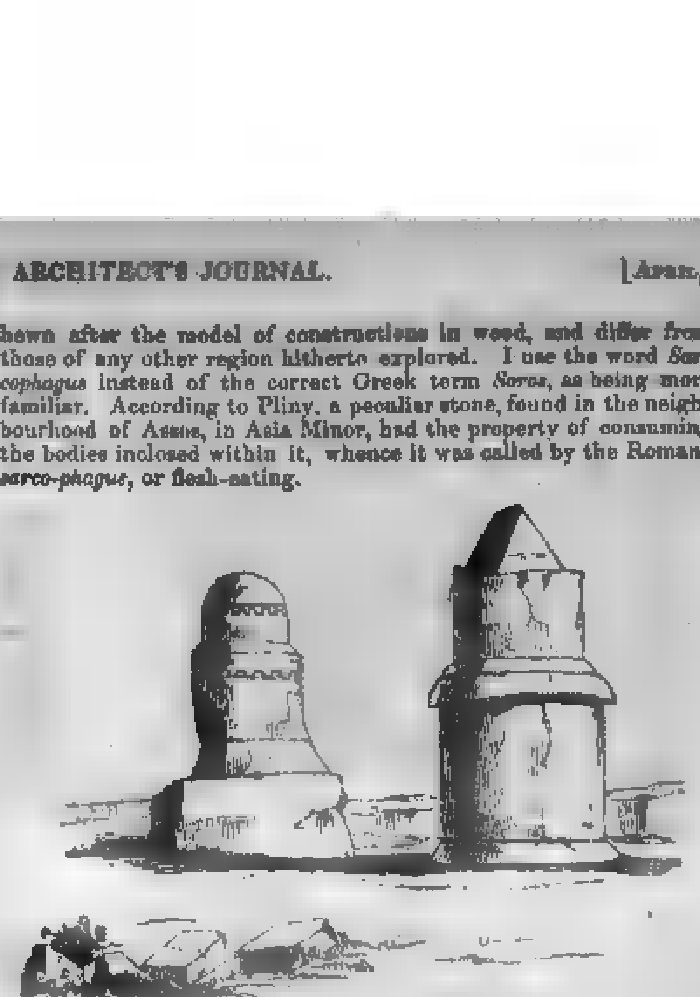
tomb at any rate is real, and remains to this day. The rock upon which it is carved is of volcanic tufa, isolated, and presenting a surface of about 1316 square feet. The sculptured surface, exclusive of the margin and pediment, is about 41 feet by 37 feet. The outside measurement of the niche is about 17 feet wide and 3½ feet deep; but the interior is not above 6½ feet in width, and so shallow, that it is difficult to conceive how a human corpse could have been deposited there. The niche must formerly have been closed by a slab of stone, upon which the ornamental pattern was continued. Over the pediment are two circular forms, meant to represent either shields or volutes; and there are other richly-sculptured façades in the neighbourhood, with similar ornaments.

The custom of suspending shields, not only over sepulchres, but on the city walls and on the temples, was so ancient and universal, that there is every reason to believe such to have been the origin and intention of these ornaments, even when they take a more volute-like form. Ezekiel alludes to this usage in chap. xxvii., v. 11; "They hanged their shields upon thy walls round about; they have made thy beauty perfect;" and we know that the ancient Greeks frequently presented shields as votive offerings, when they were suspended on the walls of the temple.

Many Phrygian tombs are sculptured in the form of a richly-ornamented and panelled doorway; but the door is fictitious, the opening to the tomb being above. These tombs are entered by shafts pierced in the rock, with niches in the sides, at intervals, to facilitate the descent. In some instances, the excavated rock-chambers communicate by means of these chimney-like shafts; so that tier after tier, and chamber after chamber, may be traversed, like a vast mine in the heart of the mountain. In some caves, sarcophagi are found; in others, funeral beds; and, in many, no traces of their having been occupied, either by dead or living.

In Lycia and Xanthus, the tombs differ widely from those of Phrygia; many of the excavated chambers have apertures singularly resembling the heavy mullioned windows of the middle ages; these are generally finished with denticulated ornaments and pediments. In Xanthus, sepulchres are found in the form of towers, something resembling in form high pedestals: perhaps they may formerly have supported sphinxes, or statues. The tower or pillar is a very ancient form of monument, immediately succeeding the stone of memorial; there are two of great antiquity in the north of Syria, between Tripolis and Tartous. The pedestal of the first is about 6 feet in height; on this there are said to have been four sphinxes, but they are now too much mutilated to be recognisable. On the pedestal stands a circular column, about 20 feet in height, divided into two parts, by a denticulated ornament, and surmounted by a small pyramid. The other pillar or tower stands at a distance of about 30 feet from the first, and is of similar form, except that the summit is dome-shaped, instead of pyramidal.

The most remarkable tombs in Xanthus and Lycia are those in the form of sarcophagi, raised upon a pedestal; they are evidently hewn after the model of constructions in wood, and differ from those of any other region hitherto explored. I use the word *Sarcophagus* instead of the correct Greek term *Soros*, as being more familiar. According to Pliny, a peculiar stone, found in the neighbourhood of Assos, in Asia Minor, had the property of consuming the bodies inclosed within it, whence it was called by the Romans *sarco-phagus*, or flesh-eating.



Ancient Towers north of Syria.

The Lycian and Xanthian sepulchres display a mixture of Greek and Persian, or perhaps Assyrian taste; many of them are richly decorated with bas-reliefs, as may be seen by referring to the Xanthian marbles in the British Museum. One great peculiarity of these tombs is the high-pitched roof, though such must have been familiar to Homer, for in a passage in the Iliad, he compares Ajax and Ulysses grasping each other in wrestling to the pointed roof;—

> "Close locked above, their heads and arms are mix'd,
> Below their planted feet at distance fix'd;
> Like two strong rafters which the builder forms,
> Proof to the wintry wind and howling storms;
> Their tops connected, but at wider space,
> Fix'd on the centre stands their solid base."
>
> —Iliad.

In Caria, also, the sepulchres are elaborate and beautiful. According to Mr. Hamilton, they form three sides of a square, the fourth being against the side of a hill, and must have the appearance of porticoes leading to temples within the rock. At Halicarnassus, in this kingdom, was the celebrated tomb of Mausoleus, king of Caria, erected to his memory by his widow, Artemisia, who is said to have drank up her husband's ashes, in despair, at his death. Unlike many inconsolable widows, she never married again, but died broken-hearted in less than two years, after having superintended the erection of this splendid monument, intended to perpetuate her love and grief. This tomb stood upon a platform 411 feet in circumference; four architects were employed in its construction; and as it was built at the time of Greek pre-eminence (about 358 B.C.), was doubtless in the Greek style. It was called the *Mausoleum*, and was so renowned for its beauty, that it has given a name to all magnificent places of sepulture of subsequent erection.

In the Troad, and in Lydia, it was the custom to construct a tumulus over the grave. Mr. Hamilton says, that in one plain in Lydia, there are upwards of sixty tumuli, called by the Turks Ben Tepéh (the thousand hills.) The largest one, known as the Tomb of Halyattes, is nearly half-a-mile in circumference. I have mentioned the antiquity of the custom of burying under a tumulus in a former lecture. Homer refers to it in the following passage:—

> "Now all the sons of warlike Greece surround
> Thy destined tomb, and cast a mighty mound;
> High on the shore the growing hill we raise,
> That wide the extended Hellespont surveys;
> Where all from age to age, who pass the coast,
> May point Achilles' tomb, and hail the mighty Ghost."
>
> —Odyssey.

It would be neither interesting nor instructive, to enter further into the antiquities of Asia Minor, rich as it is in remains of the rarest architectural works. The beautiful ruins of Ionia, Ætolia, &c., will be included in the history of Greek architecture; and any further notice of those existing previous to the rise of the Hellenic colonies, would but be a tedious list of Cyclopean and

Pelasgic walls and gateways, in no essential point differing from those already described.

Deeply interesting as is the history of the Jews in other respects, as far as regards architecture it is almost a blank. The Jews, having been a pastoral people, never became great builders, and acquired no style of their own. Though Jerusalem is a city of great antiquity, having been founded (according to Manetho) by the Hycsos after their expulsion from Egypt, we have no description of any of its buildings previous to the erection of Solomon's Temple. The first Jewish structure on record is the Tabernacle, which Josephus describes as "a moveable and ambulatory temple." It was 52 feet in length by 21 feet in breadth and height, and had twenty quadrangular pillars on each side, and six at the end or posticum. The front was placed so as to have an eastern aspect, that it might catch the first rays of the sun. The pillars were of wood, covered with thin plates of gold; and as the structure was to be moveable, the pillars were fitted into their bases, and the gold or gilt bars forming the architrave into each other, by a tenon and mortice, so that they could easily be taken down, and set up in a new place. The interior of the Tabernacle was divided into three parts, as it might be the vestibule, pronaos, and adytum; the latter being the most holy place, where the ark was deposited. The Tabernacle was placed in the midst of a court, or sacred inclosure, formed by slender brazen pillars or staves, with cords from one to another, on which curtains were hung; these staves terminated in a sharp end, like a spear-head, which was stuck firmly in the ground. Within the court was the brazen laver or vessel for purification.

We learn from the sacred writings, that when David built his house, he sent for an architect from Phœnicia; and king Solomon followed the example of his father, when preparing to build his temple and palace at Jerusalem. Hiram, king of Tyre, not only sent an architect, but also provided other workmen, and much of the necessary materials. It is very difficult to obtain any clear conception of the Temple of Solomon; the description in the 1st Kings, and 2nd Chronicles, dazzling the imagination with a vague idea of gorgeousness, but not giving sufficient data for an accurate plan. Many different opinions prevail on the subject: Mr. Bardwell, says, "the temple of Solomon had not in its proportions and details any thing in common with the temples of Greece;" and presumes it to have been altogether copied from those of Egypt; while Mr. Wilkins, in his valuable work on Magna Græcia, supposes the Temple of Solomon to have been the model after which the Greek temples were constructed. Objections may be made to both these opinions. The Temple, which was to be a stationary Tabernacle, closely resembled it in proportion and distribution of parts; and so far, the first idea of the building may have been borrowed from what they had seen in Egypt; but it is scarcely likely that the Hebrews would have been desirous of building a temple to the Most High, constructed exactly after the model of the idolatrous temples of the abhorred land of Egypt, every recollection of which was so associated with slavery and degradation, that even brick-making became as great an abomination in their sight, as the Shepherd life was to the Egyptians. On the other hand, it is unlikely that the Greeks should have copied from Solomon's Temple; they had no religious motive for so doing, and had but little intercourse with Judea. Josephus, in his letter against Apion, says, "there was no occasion offered us in ancient ages for intermixing among the Greeks;" and afterwards observed, that being an inland people, the Hebrews were comparatively unknown to them. The most probable conclusion is, that as a Phœnician architect was employed, he would construct the Temple of Solomon as nearly as possible after the plan of those of his own country; and as there is little doubt that Greek architecture also originated in Phœnicia, there would naturally be a great similarity between the Jewish and Greek temples, though the plan would be adapted to the requirements of the people, and their peculiar mode of worship.

Three years were occupied in preparing materials and hewing stones for the temple of Jerusalem, and seven years more in its erection; the walls were constructed of stone covered with cedar, and the roof entirely of cedar wood. Josephus says, speaking of the skill displayed in the masonry, that the polished stones were "laid together so very harmoniously and smoothly, that there appeared to the spectators no sign of any hammer or other instrument of architecture; but as if, without any use of them, the entire materials had naturally united themselves together, that the agreement of one part with another seemed rather to have been natural than to have arisen from the force of tools upon them." The interior of the temple was divided into two parts, the oracle and the sanctuary; there was also a porch or vestibule before the front of the temple towards the east.

The proportions of the building (taking the cubit at 21 inches,) were, including the porch, 140 feet in length, by 35 feet in breadth; the oracle was a cube of 35 feet, the sanctuary 70 feet in length, the remainder being given to the porch. Instead of a peristyle, the Temple of Solomon was surrounded on three sides by a number of small cells or chambers three stories high, each chamber 8 ft. 9 in. square, thus giving a total width to the building of 43 ft. 9 in. This arrangement was not unique: there are the ruins of a temple in Lydia which has a set of small cells extending the whole length of the flank. Access was gained to the upper stories by a staircase in the thickness of the wall, and light admitted into the sanctuary by a row of narrow windows or loop-holes above the chambers. The whole of the interior of the temple, including floor and ceiling, was overlaid with gold. The oracle was divided from the sanctuary by a pair of folding doors of carved cedar wood richly gilt, and also by coloured and embroidered veils of fine linen: the sanctuary had similar doors leading to the porch. In the porch were the two great pillars, called Jachim and Boaz; these were massive brazen columns, with vase-shaped capitals, enriched with net-work and foliage. Round the temple were three courts, each one elevated a few feet above the next. The highest, nearest the temple, was called the Priest's court, because the priests only were permitted to enter; here stood the great brazen altar, and the molten sea, and other lavatories; this sacred inclosure was surrounded by a wall between 5 and 6 feet in height. The next, the court of Israel, was quadrangular, contained cloisters, and was entered by a great gate on each of the four sides; into this, says Josephus, "all the people entered that were distinguished from the rest by being pure and observant of the laws." The outer division was called the court of the Gentiles; this was surrounded by a double row of cloisters, supported by stone columns, and roofed over with polished cedar; here only the public were freely admitted.

This magnificent edifice was destroyed by Nebuchadnezzar, 586 B.C. The temple was rebuilt on the return of the Jews from captivity, but not in its original splendour, for we are told that when the festival of its completion was celebrated, the old men and priests, remembering the superiority of the original building, broke out into tears and lamentations, so that "their wailing overcame the sounds of the trumpets and the rejoicing of the people." This second temple, after sustaining various injuries, such as having been plundered by Antiochus Epiphanes, and desecrated by Pompey, was consumed by fire during the siege of Jerusalem by Titus, A.D. 70.

The Palace of Solomon was situated near the temple, and must have vied with it in splendour; it appears to have been arranged on a similar plan to the Eastern palaces of our own day, in large open courts, surrounded by different apartments. Solomon's palace consisted of three divisions, the centre one containing the great hall of judgment and other public offices; the rest of the building formed the residences of Solomon and his Egyptian queen. The principal apartments are described as having floors of cedar; the walls were inlaid part of their height with polished marble. Above this was a row of sculptured slabs representing foliage, and between these slabs and the ceiling the wall was plastered and richly painted; thus closely resembling the interior of the palaces of Nineveh. There were also cloisters for exercise, and, according to Josephus, "a most glorious dining-room." He continues: "Now it is very hard to reckon up the magnitude and the variety of the royal apartments; how many rooms there were of the largest sort, how many of a size inferior to those, and how many that were subterraneous and invisible, the curiosity of those that enjoyed the fresh air, and the groves for the most delightful prospect, for the avoiding the heat and covering of their bodies; and to say all in brief, Solomon made the whole building entirely of white stone and cedar wood, and gold and silver. He also adorned the roofs and walls with stones set in gold, and beautified them in the same manner as he had beautified the Temple of God with the like stones."

Of the private houses of the ancient Jews we know little, except that they were flat-roofed, and of two or more stories, as frequent mention is made of "the upper chamber." The flat roofs were used, as in the East at the present day, both for exercise and repose, and it was commanded by law that each house should have the roof protected by a parapet.

Most of the buildings now existing in Palestine are Saracenic; the most ancient do not date beyond the time of Herod, with the exception of the tombs of the Patriarchs. The celebrated Sepul-

chre of the Kings, near Jerusalem, is undoubtedly Roman in design; it is by some supposed to be the work of Herod, and by others to be the tomb of Helena, queen of Adiabené, who had become a convert to the Jewish faith: there are still the remains of a beautifully sculptured façade; a low doorway conducts into a large chamber, hewn out of the solid rock; from this branch off several small crypts, with ledges on which to deposit bodies or coffins; a flight of steps leads to a lower set of chambers, similar in form and arrangement to those above: here some beautiful white marble sarcophagi were found.

The Tombs of the Patriarchs are situated in the valley of Jehoshaphat, on the eastern side of the Brook Kedron; the names assigned to them are the Tombs of Jehoshaphat, James, Zachariah, and Absolom: the two latter are the most elaborate. M. de Chateaubriand speaks of these tombs as displaying a manifest alliance of the Egyptian and Grecian taste; "from this alliance," he says, "resulted a heterogeneous kind of monument, forming, as it were, the link between the pyramids and the Parthenon."

The Tomb of Zachariah is shown in the engraving; it is monolithic, and consists of a square, with four engaged Ionic columns and two pilasters on each side. The Ionic are of the rudest kind, and bear the stamp of great antiquity. The entablature is finished with the ancient bead-and-cavetto moulding, and the whole surmounted by a pyramid.

Tomb of Zachariah.

The Tomb of Absolom consists of a mass of rock, 21 feet square, standing in a recess of the hill which surrounds it on three sides. It has two engaged Ionic columns and two pilasters on each side; the frieze is ornamented with triglyphs; on this square stands a dome, and above this again a spire, the summit of which expands like a bell-shaped flower. This is supposed to be the building referred to in 2 Samuel, xviii. 18: "Now Absalom in his lifetime had taken and reared up for himself a pillar, which is in the King's Dale; for he said, I have no son to keep my name in remembrance, and he called the pillar after his own name; and it is called unto this day, Absalom's Place."—The tombs of Jehoshaphat and James are simple excavations.

The art of fortification was always encouraged by the Jewish kings. Jerusalem, and especially its citadel, Mount Zion, was well defended by strong walls and towers; these have now given place to more modern fortifications. Well may the Jews keep the Day of Desolation in gazing upon Jerusalem, when of all the magnificent and stately buildings that once adorned it, not a ruin remains: but, instead, Roman walls and Saracenic mosques, telling of a succession of conquerors. Palestine has still much to engage the attention of the antiquary, but little, as has been seen, to attract the architect in his inquiry into the architecture of the Jews.

In the next lecture I shall speak of Etruria, stone buildings after the wooden model, and the foundation of Rome.

LIST OF AUTHORITIES.

Ancient and Modern Architecture, Gailhabaud.—Travels in Greece, Dodwell.—Travels in Greece, Dr Clarke.—Tour in Greece, Dr. Wordsworth.—Cyclopean and Pelasgic Remains, Dodwell.—Antiquities of Athens, Stuart and Revett.—Descrizione di Cere Antica, Canina.—Magna Græcia, Wilkins.—Notes on Vitruvius, Wilkins.—History of Greece, Grote.—Cities and Sepulchres of Etruria, G. Dennis.—L' Italia avanti il dominio dei Romani, Micali.—Asia Minor and Lycia, Sir C. Fellows.—Travels in Asia Minor, Hamilton.—Voyages en l' Asie Mineure, Laborde.—Voyages en l' Asie Mineure, Texier.—Homer, Pope's translation.—Bible History of Palestine, Kitto.—History of the Jews, Josephus.

PRINCIPLES OF DESIGN.

Rudimentary Treatise on the Principles of Design in Architecture, as Deducible from Nature, and Exemplified in the Works of the Greek and Gothic Architects. By Edward Lacy Garbett, Architect, Parts I. and II. London: Weale, 1850.

We have a well-known line of Homer, that "life is a mingled skein of good and ill:" and this is what we must say of this book, to give anything like a knowledge of it. There is ill enough in it to condemn any book; and yet there is as much good as would make a book. If it were a work on strict science, the failings would be fatal; but as it is on a debateable and unwrought subject, perhaps we owe much to the writer for what is new, true, and good, instead of having any right to blame him for what is otherwise.

It was a token of health when the outcry began about the want of taste and originality in building—this set men thinking; but had this gone on, we should have been brought to a more sickly mood than we were before. It is easy to blame; any one can do that—it costs nothing; even the youthful critic is sharp enough in finding out a blot, a blunder, or a want: and the world, always ready enough at it, was set grumbling. Grumbling is good, if we have not too much of it; but we wanted something more—we wanted to know what was to be done, as well as what was not to be done. That is the step to which we have now come, and it is a further token of health.

So long as humdrum swayed, woe betide the unlucky wight who strove for anything new; the herd of dullness' sons soon brought him to the ground. The way, however, is now opened; men may think and do, if they know what to do; the chains of mock classicality are snapped asunder, and skill is free. Slowly has a school of criticism risen, such as we have never yet had: and if the laws of knowledge are not yet settled, if the whole field is not beaten, and every nook searched out, yet we have hope before us, which we have never had before. The works of Leeds, Pugin, Jopling, Alison, Whewell, Willis, Hay, Ferguson, Ruskin, and we shall have to say, of Mr. Garbett, have each laid open something new.

If, however, any one thinks all is now right, and watchfulness at an end, he will reckon without his host. The cant of classicism we have got rid of; but the cant of criticism threatens us. Quackery is not so soon laid; it is a ghost which takes many shapes—and when driven from one, grins at us in another. There is little need of warning as to the 'Seven Lamps' of Mr. Ruskin; quackery is written on the forehead—the mysticism of the Seven Lamps wears throughout: but there is likewise some of it elsewhere.

To review Mr. Garbett's book, we should need to write another at least as long, for at every leaf there is something to be said; but as we do not feel the call upon us to undertake such a task, we must lighten our work by again telling the reader, that it is a book from which he may learn a great deal, but must not believe everything that is set down for him. The end Mr. Garbett has in sight is, to lay down the laws of design as drawn from nature; and this is a great thing to be done. Why he has so often missed, and why so many others have missed, is from having gone about it in the wrong way.

The groundwork of all lawmaking is a thorough knowledge of things. We hardly need Bacon to teach us this; and yet all this is to be done for the work Mr. Alison and Mr. Garbett have undertaken. It was the want of this, which, under the Aristotelian school, brought every kind of knowledge so low; and in nothing perhaps was this so striking at the new birth of learning, than in the knowledge of beasts. Othello's gleanings of natural history, "of men whose heads beneath their shoulders grow," were got from the field of learning. The Hortus Sanitatis, or any other black-letter book of the kind, will show what were the laws of nature believed in in Shakespearian times: and so far as design goes, we are not much better off now, and on the very same ground, inasmuch as no one has undergone the toil of setting down every shape to be seen in nature, and drawing the laws from them. The laws have been drawn up first; such things as help them, brought forward; the things against them left out of sight, or twisted in some wrong way.

The want of a sound groundwork has made much of Mr. Garbett's building rotten; but we are bound to acknowledge that he has done the best he could. He has an earnestness in his work, an enlightened feeling, good knowledge of his business, and is thoroughly well read in the learning of art. He neither blindly follows any man, nor stubbornly sets himself against him; what he thinks right in any one, he takes with fair acknowledgment: and if he or any of the others had, indeed, settled the laws of nature or of design, his would be a good hand-book on the subject.

What Mr. Garbett has done, shows moreover what may be done; that art is not without laws, though we do not know them all. When the reader has gone through this book, he has still to read Fergusson and the others, to make up his mind what he will believe and follow out. Nevertheless, we may fairly say Mr. Garbett's book is a step forward.

Having shown what is the root of the evil, we shall not put the book away without a few words as to some of its teachings. Mr. Garbett lays it down, that no building has a right to be selfish; but he rides this hobby too far the wrong road, being afraid, as he says, of going on that to communism. This is some of the cant of the day; and is giving a worth to a name which does not belong to it. If a thing is right, we may stick to it without fear of its name; and we need not wander from the field of building, for a stalking horse on the field of politics. If man is not made to be selfish and live alone, then it is his bounden duty in a building, as in everything else, to show some feeling for his fellows. As he can have no right of himself, but only by the law of the land, to run up a building, so he can have no right to run up a building which is unsightly. The least he can do, if only as a reward for the leave given to him, is to build right.

We may say, by-the-bye, that Mr. Garbett gives his meaning to the word æsthetic—a word which is a stumbling-block laid in the way of art by our High Dutch neighbours; and which the sooner it is got rid of the better, for what it means no one knows. We are sent back to *aisthetikos*, and thence to *aisthanomai*; then we are brought forward from the Greek and Greek-English to Latin-English; and told that æsthetic means *sensuous*, or *relating to the senses*, which in English are the feelings. Æsthetics seems to have been meant by the High Dutch for the knowledge of the laws by which beauty impresses the feelings; but esthetic may mean a number of things, as it is understood in its several Greek, Latin, English, or High Dutch relations.

REPORT OF THE COMMISSIONERS APPOINTED TO INQUIRE INTO THE APPLICATION OF IRON TO RAILWAY STRUCTURES.

The last notice of the Report of the "Iron Commission" referred to the manner in which empirical formulæ had been obtained for connecting the longitudinal compression and extension of cast-iron with the corresponding elastic forces. "The law of elasticity," it is said in Appendix A, "constitutes the very basis of all sound knowledge of the statical and dynamical properties of girders."

The "revision of that law" is undertaken as one of the subjects of this Appendix. The investigation was conducted by one member only of the Commission—Mr. Hodgkinson—whose experience and persevering research as an experimenter, render empirical deductions obtained by him worthy of the most careful consideration.

In the preceding number of this *Journal* (*page* 92), was given one of his tables for Extension of Cast-Iron, showing the relation between different suspended weights, and the extensions produced by them.

The results of computing the extensions from a certain empirical formula are also given, and the errors or deviations from the observed results. These errors, in five cases out of fifteen, deviate from the real result by about one-fiftieth part; the smallest of the remaining errors is the two-hundred-and-eighty-fourth part. Now, although these errors may seem small in themselves, they cease to appear so when it is reflected, 1st, that the empirical law assumes the character of "the very basis of all sound knowledge of the statical and dynamical properties of girders;" 2nd, that the formula is not deduced from abstract theory, but from the experiments themselves, and is in fact no more than a synopsis of their results.

Under the first head, we observe that any error in the empirical law becomes enormously multiplied when it is applied to the theory of girders. The result of integration and other analytical processes involved in that theory, is that the magnitude of the original error is not at all commensurate with the magnitude of those it induces. We are to remember that the old law of elasticity (that of direct proportion of the longitudinal forces to the extension or compression) led to the inference, that in a girder the central deflection and transverse pressure were in direct proportion also. This result, however, was not *quite* true. A *small* increase of deflection above that due to the proportional increase of pressure was observed; and the former increase was due to a *small* error in the assumed law of elasticity. It may easily be supposed that this "small increase" and "small error" (though small considered separately with reference to the results from which they were respectively derived) are not small with *respect to each other*. This is the best way in which we can put the argument, without aid of mathematical language: *that* would show that the "defect of elasticity" of the deflected girder is a quantity of the same order as the "defect of elasticity" of the longitudinally compressed or extended rod.

In the table above referred to, the "errors" or deviations of the formula from experiment, are given "in parts of the real weight" stretching the rod: but if the errors had been given in parts of the much smaller quantity—"the defect of elasticity"—they would have appeared much larger.

The second head of our remarks is this, that the formula is essentially empirical. It depends on no abstruse investigation; and all that is required is a method of representing observed results in the short-hand of mathematics. The way in which this has been done, appears unscientific in its principle as well as unsatisfactory in its results. Two empirical coefficients a and b were to be obtained in a formula

$$w = ae - be^2,$$

where w is the tensile force and e the extension.

If the formula were absolutely exact, and experiments could be made which were absolutely exact also, two experiments would suffice to determine a and b. But, because that accuracy is practically unattainable, it was of course the case that any pair of experiments would give values of a and b differing from those of another pair of experiments: we have a remarkable instance of this at page 58, where it is stated that by one pair of experiments, the value of b obtained was 177290·03, and by another pair, the value of b was 221163·17.

Now, in selecting the pairs of experiments for this computation, no sort of system or scientific method appears to have been adopted—the selection was made entirely at random. This process *might* have produced satisfactory results, but the chances were immeasurably against its success. At all events, the accuracy of the final formula so obtained could not but rest on a much lower kind of evidence than that in favour of a formula formed in accordance with the mathematical laws "in that case made and provided."

The mathematical laws of combination of observations are definite and exact. Practical astronomy is almost made up of such combinations, in which several results are to be represented by a formula which shall give the closest possible approximations. The importance of the subject in physical science long ago led mathematicians to perceive that they must combine their results by fixed principles, and not by taking averages indiscriminately. Gauss, the author of the *Theoria Combinationis Observationum*, proposed the celebrated rule of Least Squares, which has been independently discussed by Legendre, Laplace, Poisson, Ivory, and others.

To the kindness of Mr. ADAMS, Fellow of St. John's College, Cambridge, we have been privately indebted for copious examples of the application of the method to the case before us; he has also pointed out a very simple method of extending the formula, to include the *cube* of the extension. The agreement of the theoretical and computed results then becomes extremely close and accurate; when two terms only are taken by the method referred to, though the formula is considerably improved, it still falls short of the required degree of accuracy. This systematic method of computation has the advantages not only of superior accuracy but of superior facility—the labour which it involves is far less than that required by taking averages without regularity of order.

We may quote the same high authority for the opinion that the experiments on COMPRESSION, given in the Report, cannot be represented accurately by a formula involving even the third power, still less by one extended only to the second power. A very careful consideration has led us to the conviction that the irregularities arise *in the experiments themselves*, and that the errors of observation are probably much greater than in the experiments on *tension*.

The experiments on compression were made in this way:—a bar, 10 feet long by 1 inch square, was inclosed in a strong iron frame, open at both ends, to permit the free compression of the bar longitudinally, but to prevent, as far as possible, its lateral flexure.

The frame was made in two parallelpieces, which were screwed together, and thus adjusted, as nearly as possible, to the size of the bar; so that it "had thepower of being moved by the hand, but no power of deviation from the right line of its position." In other words, there was a good fit, but not a tight one.

Unfortunately, however, though the bars were intended to have no power of deviation from the right line, they assumed it for themselves. Whether that the frame was not screwed up sufficiently at first, or that it was not strong enough, or that the screws yielded, certain it is, that this bending of the bars, which it was all-important to avoid, actually took place. At page 64 we find the following:—

"*Remark.*—The great difficulty of obtaining accurately the decrements and sets from the small weights in the commencement of the experiments, rendered those decrements and sets, particularly the latter, very anomalous; it was found, too, that some of the bars which had been strained by 16 or 18 tons had become very perceptibly undulated. It has not been thought prudent, therefore, to draw any conclusions from bars which have been loaded with more than 14 to 16 tons; and it may be mentioned that the results from 2 to 14 tons are those only which ought to be used in seeking for general conclusions."

Now, if the bar "*very perceptibly* undulated" in some cases, it is reasonable to suppose that it undulated in less degree in others. A flexure quite inappreciable by the naked eye would altogether vitiate any inferences from the experiments as to the law of elasticity. The contraction of the rod after it has been bent, is no longer measured solely by compression in the direction of its length, but partially by the diminution of the chords of certain curves—the curves of flexure. And it is to be remarked, that the diminution of these chords affects more especially those very terms in the formula which are principally sought for—the terms after the first, which express the defect of elasticity.

Moreover, leaving the geometrical consideration, in a mechanical point of view the case presents great difficulties. The external compressing force is no longer resisted by direct compression alone, but by compression and transverse pressure compounded. Again, if the bar closely fitted the interior of the frame originally, it must have bulged the sides of the frame when it got bent. Consequently, at those points where the bar most deviated from the right line, it must have pressed strongly against the frame.

Now, the effects of the pressure in question may be illustrated as follows:—Let a thin, flat rod of wood, whalebone, or steel, be placed on a table, and abut at its two ends against fixed points, so as to curve slightly upwards from the table. It will be seen that a very slight pressure on the summit of this curve will produce a very greatly multiplied pressure on the points of abutment; also the multiplication will be greater as the rod is less bent.

It is obvious from this, that the bent cast-iron rod, by pressing against the sides of the inclosing frame, must have derived great support to resist the external force to which the experimenter subjected them. Obviously, serious errors would arise from supposing the only external forces acting upon the bar to be those applied at its ends.

These considerations lead to the anticipation that the experiments would present anomalies: and this certainly appears to be the case. Without minute reference to the actual figures of the tables, the whole of the anomalies could not be specified: their general nature may, however, be briefly indicated.

1st. The ratio of the compressing weight to the compression ($\frac{w}{d}$ in the tables), instead of regularly decreasing in each set of experiments, alternately increases and decreases in an irregular manner. There are four kinds of iron—Low Moor, Blaenavon, Gartsherrie, and a mixture of Leeswood and Glengarnock—for which the ratio is given (pp. 65 and 66). The first three sets of experiments consist of thirteen results each, and the last set of twelve results. Let us suppose the results numbered in their numerical order, 1, 2, 3, &c., and let + or − indicate that the ratio for one result is greater or less, respectively, than that which follows it. Then, for the results on each iron, the fluctuation of the ratio will be expressed as follows:

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Low Moor	−	+	−	−	+	+	+	−	−	+	+	+
Blaenavon	+	−	+	+	−	+	+	+	+	−	+	+
Gartsherrie	+	+	−	+	+	+	+	+	−	+	+	+
Leeswood & Glengarnock	+	+	−	+	−	−	+	+	+	+	+	

The plus sign occurs 34 times, and the minus sign 13 times, in the above synopsis; consequently, as the plus sign indicates a descending ratio, the number of ascending ratios is more than one-third the number of descending ratios. Now, in the formula of the Report, it is assumed that the ratio constantly descends; accordingly, the abnormal are more than one-third of the normal results. It may be shown, by simple analytical reasoning, that if the formula include only two terms, the ratio of the weight to the compression must be either always ascending or always descending; that if the formula extend to three terms, the ratio may be ascending to a certain point, and then descending, or conversely; and that if the ratio be ascending and descending several times alternately, there must be more terms in the formula.

2nd. The experiments for different sorts of cast-iron indicate widely-different physical properties in them. The ratio of the weight to the compression differs greatly for corresponding experiments in the four different sorts of iron: and not only is the ratio different absolutely, but its fluctuations are different also. This is shown in the foregoing synopsis, and a remarkable instance occurs in the tables on the two last kinds of iron, of which the first is represented as much less easily compressible than the latter at the beginning of the two sets of experiments, and more easily compressible at the end of those experiments. This may be possible, but it is not probable. At all events it renders invalid all general inferences taken from collecting (as at page 67) the means of the results for materials exhibiting such different properties; just for the reason that it would be improper to collect in one table the experiments on marble and ivory, and deduce a single formula for the elasticity of both. But this is precisely the way in which the formula for compression of cast-iron has been obtained.

It is to be observed, however, that in the table in which the mean results of compression *of all four* sorts of iron are given, the ratio of the weight to the compression is generally a descending one. This circumstance removes the impossibility of expressing the elasticity by a formula of two terms. It is barely possible also, that in thus collecting the means, the errors of the original experiments might destroy each other. But when the errors inseparable from the methods of those experiments, and the discrepancies among them, are considered, such a compensation appears extremely improbable.

The formula is obtained only from the mean results of all the irons—no formulæ are given for each iron separately. The foregoing considerations explain this circumstance. In the experiments of *tension*, however, where the results are much more trustworthy, and *the ratio is a descending one in every case with a single exception*—formulæ are given for each iron. The omission of formulæ for each iron compressed cannot, therefore, be considered accidental: if attempts to supply such formulæ have been made and omitted from the Report as unsuccessful, the failure must be attributed to the analytical principles which we have above enunciated.

Doubtless, experiments on compression of long bars present great difficulties; but we can conceive of no method of insuring their accuracy while the inclosing frame is retained. The fact of such a frame being required manifests that the experiments are not what they profess to be—experiments on direct compression—but experiments on compression and flexure combined.

If the subject be taken up anew, some means must be devised of compressing the bars without the chance of lateral support interfering with the accuracy of the results. But to compress the bars in this way, they must have such a section—the cruciform, for instance—as of itself has great power to resist flexure. If the compressing force be applied by a lever, the angle through which it moves in the course of the compression might be read off by the microscope. We offer these suggestions by no means confidently, but in the hope that they may stimulate endeavours to solve a most important practical problem.

In the case of tension, the experiments seem comparatively free from difficulty. It might perhaps have been worth while to have given a correction for the effect of the weight of the rods themselves, and the couplings, which were heavy masses of metal: and this correction might have been applied without much difficulty. In other respects, the results of experiments on tension appear exempt from general causes of error.

We have somewhat minutely examined the subject, because of its great practical importance, and because we have questioned the validity of the formulæ for compression and extension proposed as the basis of theory of girders. But as these formulæ are given on the authority of an able experimenter, who has the highest claims to respect, we shall be glad to find that the views here expressed have been reviewed, and if need be, revised, by investigators of high scientific repute.

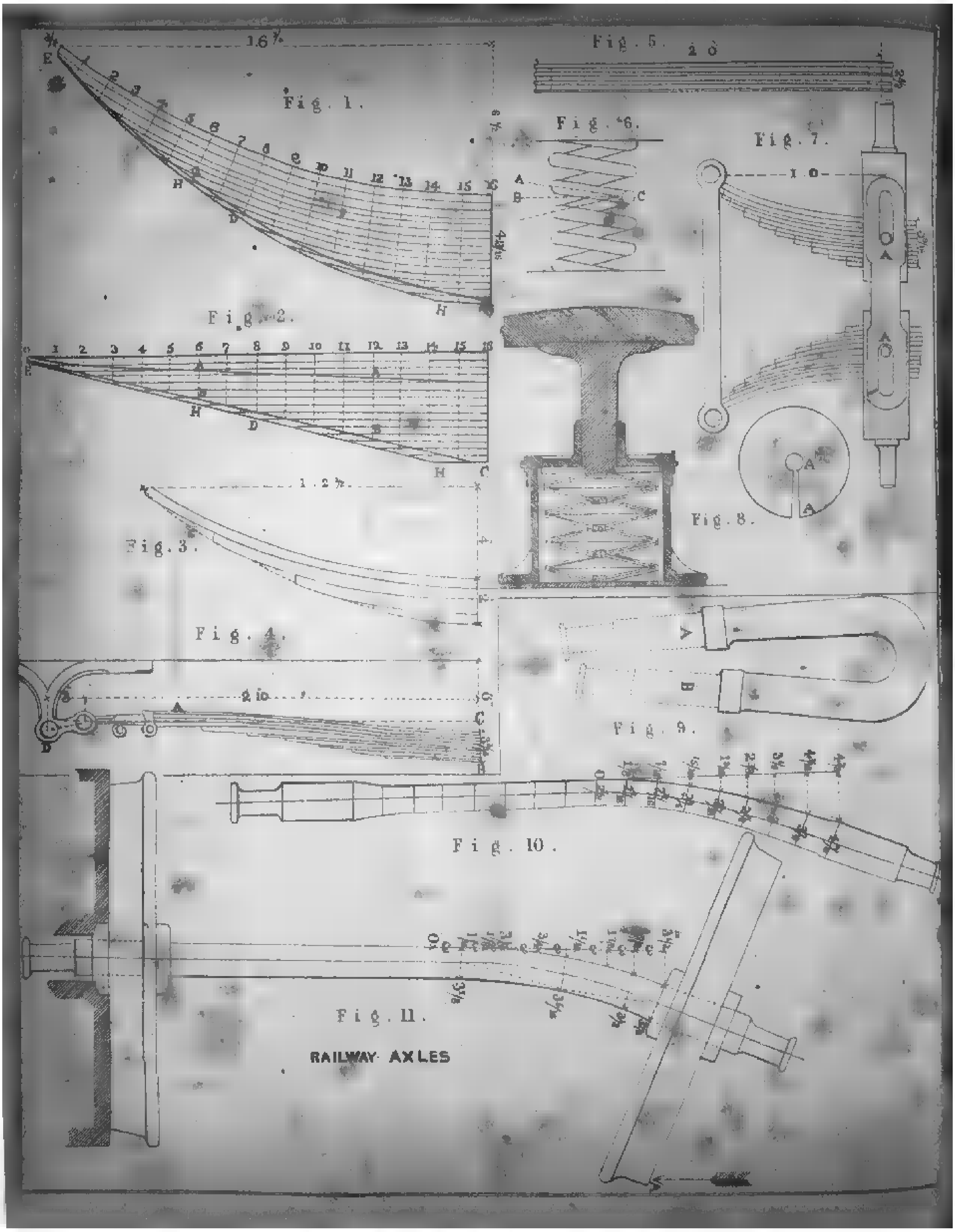


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
RAILWAY AXLES

RAILWAY CARRIAGE AND WAGON SPRINGS.

(*With Engravings, Plate* IV.)

On Railway Carriage and Wagon Springs. By Mr. J. W. ADAMS.—(Paper read at the Institution of Mechanical Engineers.)

THE object of this paper is to discuss and analyse the various forms and descriptions of springs now in use in Railway Carriages and Wagons; pointing out, to the best of the writer's knowledge and experience, their advantages and defects, and suggesting such improvements in the details as will lead to better effect and economy in their use and manufacture.

Buffing and bearing springs are applied to carriages and wagons in order to absorb and neutralise as far as possible the force and momentum of the shocks to which the vehicles are exposed in their ordinary work. A perfect bearing or buffing spring would be that which would absorb the entire power and space of the blow without disturbing the inertia of the vehicle. This in practice is wholly impossible, from the varying loads on bearing springs and varying force on buffing springs. In bearing springs the nearest approach to perfection is in the modern first-class carriage, where the disproportion of total weight between loaded and unloaded is less than in any other vehicle.

At the present time, as far as the writer is aware, there is no rule or formula by which engineers or manufacturers can ascertain the true form, weight, or quality of material to be used for effectually springing a railway vehicle, and consequently the goods and mineral traffic of the country, averaging from 35 to 40 cwt. per spring, is now carried on springs which vary in weight from 35 to 110 lb. each.

The primary object being in all cases to discriminate between good and bad material, the writer has endeavoured to test the relative quality of spring steel converted from Swedish and from English iron. For this purpose bars of ordinary spring steel were procured from various makers, some being English and the others Swedish; the bars were all 3 inches wide and $\frac{5}{16}$-inch thick. These bars were cut to equal lengths, marked, and then made into springs and tempered in the ordinary manner; each of the springs consisting of a single plate turned over into an eye at each end, and 18 inches long between the centres of the eyes. These springs were then proved in the presence of Mr. W. P. Marshall, by means of pressure applied at the centre of each spring, the spring being supported by a pin passed through the eye at each end, which rested on rollers to allow the ends to be drawn together freely when the spring deflected. The results were as follows—

English.				*Swedish.*			
No.	Weight.	Deflection.	Permanent Set.	No.	Weight.	Deflection.	Permanent Set.
1.	15 cwt.	1 inch	no set	5.	15 cwt.	1½ inch	¾ inch
	20 „		¼ inch		20 „	3½ inch	2½ inch
	25 „	Broken			25 „	much set	
2.	15 „	1½ inch	no set	6.	15 „	2½ inch	2½ inch
	20 „	2¼ inch	1 inch		20 „	Broken	
	25 „	Broken					
3.	15 „	1½ inch	¼ inch	7.	15 „	2½ inch	1½ inch
	20 „	3½ inch	2½ inch		20 „	4½ inch	3½ inch
	25 „	much set			25 „	much set	
4.	15 „	1½ inch	¼ inch	8.	15 „	2½ inch	1 inch
	20 „	2½ inch	1½ inch		20 „	5½ inch	4½ inch
	25 „	much set			25 „	much set	
				9.	15 „	2 inch	¾ inch
					20 „	3½ inch	3½ inch
					25 „	Broken	
				10.	15 „	3½ inch	2 inch
					20 „	Broken	

From the foregoing experiments it appears that the elasticity sustaining power, and toughness of the English steel was much greater than that manufactured from the Swedish iron.

The *Laminated Spring* is the most common form for the springs of railway vehicles, consisting of a number of plates, the taper being given by reducing the plates successively in length.

The principle for regulating the taper of the spring is to obtain an equal amount of strain or deflection from each particle of material. If some parts of the spring are deflected less than others, the amount of material might be reduced in those parts without impairing the sustaining power of the spring.

A laminated spring may be tapered either in breadth or thickness, but if parallel in thickness and all the plates the same length, each plate should be uniformly tapered in breadth, so that each half of every plate would be a triangle. In practice the plates of laminated springs are made parallel in breadth and thickness, inasmuch as the parallel bar is the most economical form, and the taper is obtained, as before expressed, by the different lengths of plates.

If a spring consisted of only one plate, parallel in breadth but tapered in thickness, such taper should be in the form of a parabola, as the strength is in proportion to the square of the thickness. This form is shown in fig. 2, Plate IV, by the part AA.

Fig. 1 represents one-half of an ordinary wagon bearing spring. Fig. 2 is the same spring pressed flat, but supposing the plates not to slide over one another.

If the spring consisted of a number of very thin parallel plates, the correct form would be a uniform taper in thickness from the centre towards the ends, as shown by the portion BB in fig. 2, because the strength of each part of the spring would depend upon the number of plates at that part. In practice the most correct form of spring is between the two forms of the triangle and the parabola, but is nearer the triangle, as the thickness of the plates bears only a small proportion to the average length.

The spring shown in fig. 1 is 3 ft. 3 in. long, 3 in. wide, and $4\frac{5}{16}$ inches thick in the centre, and consists of 15 plates $\frac{5}{16}$-inch thick, excepting only the outside plates, which are $\frac{3}{8}$-inch, according to the usual practice, to allow for the plate not being supported by plates on both sides.

If this spring were a single plate of the same total strength it would be only $1\frac{1}{4}$ inch thick at the centre, and in the form of the parabola AA in fig. 2; but as it consists of a number of plates, the outline must be a line beyond that curve.

The straight line BB in fig. 2 is drawn outside the curve, giving a uniform taper from the centre of the spring to the end of the second plate, leaving the top plate its full thickness to the end. This line BB appears suitable to be adapted for the practical outline of the spring, as the deviation from correctness is only very small and gives a slight diminution in strength at the quarter length D, which is advisable in practice, because the centre C is usually weakened by a $\frac{3}{8}$-inch rivet hole, reducing the strength one-eighth at that point.

The line BB is transferred from fig. 2 to the curved spring in fig. 1 by dividing the length of the top plate into 16 equal parts by the lines from 1 to 16, which are drawn vertical in fig. 2, and radiating to the centre of the curve of the spring in fig. 1. These lines being made of equal length in both cases give the curved line BB in fig. 1. The end of the top plate is lengthened and turned down at E to give a bearing to the spring.

The writer has in practice set out all springs required by him, by drawing through the extreme points C and E a circular arc of the same radius as the top plate of the spring. The line obtained by this method is a singular instance of how near practice has approached theory by this simple method, the extreme difference being only $\frac{1}{8}$-inch.

The line HH is obtained in the same manner as before described, excepting that the spring is not tapered to the centre, but to a set-off of 2 inches from the centre, viz., from C to H. This is the form universally adopted, but it is clearly incorrect, as the centre is made proportionately weaker than the remainder of the spring, as well as being further weakened by the rivet hole through the centre.

The true and correct form of spring would be, that the centre of the spring should be at H, and the plates connected not by a rivet but with a narrow hoop. In practice the spring is clipped to and bears on the axle-box at H, and consequently the mass of steel H to C is entirely wasted.

In two plates of steel of the same length and breadth, but of different thickness, the amount of deflection caused by the same weights is in proportion to the cube of the thickness, although the breaking strength is in proportion to the square of the thickness; consequently if one spring were made with plates double the thickness of those of another spring, the first would require only one-eighth the number of plates, viz., one-eighth the weight of material to support the load with the same amount of deflection; but in that case the extent of the displacement of the particles of the steel in the thick plates would be double of that in the thin plates, and in the practical application of thick plates to springs it is necessary to limit the deflection within the above extent, as the double amount of deflection would break or strain the particles, presuming that in the thin plates the particles were being strained to a reasonable extent.

The *Wagon Bearing Spring* in ordinary use on the Midland, London and North Western, and other railways is shown in fig. 1, and is 3 ft. 3 in. long, 6½ in. camber, $4\frac{13}{16}$ in. thick, and 3 in. wide, consisting of 15 plates of which 2 are $\frac{3}{8}$-inch and the rest $\frac{5}{16}$-inch thick, and the spring averages in weight about 93 lb.

This spring is used to sustain loads not exceeding 6 tons on the four springs exclusive of the wagon body; the wagon body weighs barely 2 tons, making the total load about 8 tons, or 2 tons per spring.

By actual experiments this spring deflects with

1 ton	2 tons	3 tons
$\frac{5}{8}$-inch	2 inches	$3\frac{1}{4}$ inches

and will prove flat without setting or breaking. It is to be noted that in originally proving this spring flat it had set about $\frac{3}{8}$-inch, but that with the same extent of proof it will not again permanently set, having this property in common with other materials. This spring would well sustain a load of 3 tons in actual work, as the concussions received upon the rails would probably not at any time increase the deflection $\frac{1}{8}$-inch, consequently the load of 2 tons is being sustained on a spring far too rigid, to the detriment of the road and the wagon, and the original first cost is considerably more than it need have been. Formerly, various plans were adopted to lessen the friction at the ends of the springs by the use of rollers, but these plans are now obsolete, the amount of friction not being found practically detrimental. The points of the plates of laminated springs were formerly tapered in thickness, but now the usual plan is to form the taper in the breadth by cutting the plates at the ends in a triangular form. This method is found much more certain in its effect, is neater in appearance, and cheaper in manufacture. The cutting is generally performed either with the shearing machine or between dies in a punching machine, the scraps being used in the melting-pot for cast-steel.

Fig. 3 represents the *Wagon Bearing Spring*, or more correctly speaking, *prop*, in extensive use on the North Branch of the London and North-Western, the South Staffordshire, Caledonian, and other Railways, which may well be designated by the term *cheap*.

This spring is 2 ft. 5 in. long, 4 in. wide, 2 in. thick, camber 4 in. consisting of 4 plates $\frac{1}{2}$-in. thick, and weighs about 40 lb. Actual experiment furnishes the following deflections—

1 ton	2 tons	3 tons
$\frac{3}{8}$-inch	$\frac{3}{4}$-inch	$1\frac{1}{8}$ inch

The cause of the immense sustaining power of this spring has been explained before in the observations on thick and thin plates.

The writer has already endeavoured to explain that the ordinary spring (fig. 1) is too rigid; what therefore must be the wear and tear of rails, wheel tyres, vibration to the axles, and general wear and tear to the wagon and load caused by this rigid spring? Compared with fig. 1, this spring affords less relief in the proportion of 6 to 16, and is the furthest removed from the object required to be attained.

The *Wagon Bearing Spring* in extensive use on the Midland. Great Western, and other Irish Railways, and on the London and North Western Railway, is the ordinary spring as in fig. 1, but with eyes rolled at the ends and hung on scroll-irons. The advantages of this form of spring are the great space passed through and quickness of adaptation to the inequalities of the road, in consequence of the deflection of the end shackles caused by the deflection of the spring, and consequent elongation between the centres of eyes of shackles; also the rubbing friction at ends is almost entirely obviated. The disadvantages are, first, that to carry a given load a much greater quantity of material is required, as from the circumstance of a great portion of the space between the sole-bar and the axle-box being taken up by the scroll-irons and shackles, the radius of the curve of the spring is much reduced, and a thicker spring consequently required. Secondly, the tension on the sole-bars tending to hog the wagon frame, being the reverse of the action of the ordinary spring. Thirdly, in consequence of the great space passed through by the deflection of this spring, the variations of the load will considerably vary the height of the buffers from the rails.

Fig. 4 represents the now universal *Carriage Bearing Spring* originally introduced by Mr. Wharton on the London and North-Western Railway, as the result of repeated practical trials and improvements; theory would probably have never attained a similar result. This spring is 5 ft. 3 in. long, 3 in. wide, $2\frac{1}{16}$ in. thick, and consists of 6 plates $\frac{5}{16}$-in. thick; the ends of the plates are what is technically termed long spear-pointed. Fig. 4 represents the spring when loaded, and the peculiar camber before fixing is made by setting the plates entirely at the centre, instead of the plates being set into a curve throughout their whole length as in other springs. In fixing this spring the tension-brace is adjusted between scroll-irons, with intervening compensating shackles. The tension-brace is 3 in. by $\frac{3}{4}$-in. and thickened at the ends to $\frac{5}{8}$-in. The spring is then compressed between the axle-box and the brace. The action of the spring and brace is that of a lever spring combined with a tension-brace, but the spring is so thoroughly overpowered by the leverage of the brace and the weight of the load, as to have little or no power of reaction or displacing the inertia of the load, beyond that of recovering its original position; thus affording the well-known smoothness and steadiness of action of this construction of carriage spring. The brace is acted upon principally at the point A, but nevertheless when the blow from the road strikes the point B, and the spring and brace straighten at that point, the curving and straightening of the brace at A is compensated by the straigtening and lengthening at C, the amount of tension at D being thus at all times about the same. The tension brace steadies and counteracts the power of the spring, and the spring partly relieves the brace by sustaining it at A.

This combination also affords the means of firmly attaching the axle-box to the spring and brace, and thus holding it independent of the axle-guards, which in this case are wholly *guards*, not *guides*, the guards neither touching the axle-box on the edge or side. Thus the effects of the inequalities of the road, laterally and horizontally, are only transmitted to the body through the elastic medium of the spring.

Springs of the same construction, but shorter and lighter, are now generally used for horse-boxes, carriage-trucks, and break-vans

Buchanan's Bearing Spring consists of four flat horizontal plates 4 ft. long, 4 in. wide, and tapered in thickness from $\frac{1}{2}$-in. at the centre to $\frac{1}{4}$-in. at the ends, and fastened in the centre and impinging at the ends only. See fig. 5.

It does not seem to posess any advantage over the ordinary laminated spring, excepting that the friction between the plates is entirely avoided except at the ends; but at the same time it must be borne in mind that in ordinary laminated springs the steel is rolled concave, therefore the plates bear at the edges only, which very considerably reduces the friction.

The disadvantages of this spring appear to be, firstly, that the extreme points of support are when the spring is weighted considerably below the centre bearing, necessitating the use of deep scroll-irons in carriages and bearing-blocks in wagons.

Secondly, the manufacture is costly and uncertain, from the fact of the plates being tapered in thickness, and the difficulty of hardening and tempering plates that taper in thickness.

Thirdly, when fixed with scroll-irons the sustaining power is partly derived from its effect as a tension brace.

Adams's Bow-Spring, of the size used for passenger vehicles, is 6 ft. long from centre to centre of spring eyes, and the versed sine about 14 in. when weighted; the plates are 8 in. broad in centre and tapered in width to 5 in. at the eyes, and the thickness is $\frac{3}{16}$-inch.

The advantages of this spring are, firstly, it holds the axle-boxes without the intervention of the guards in the same manner as previously described with reference to the carriage bearing spring. Secondly, that the top links permit the wheels, axles, and axle-boxes to traverse laterally in passing curves and other impediments. Thirdly, that the quick adaptation of this spring to lateral and perpendicular blows preserves the inertia of the body almost wholly from displacement at moderate speeds.

The disadvantages are, that at high speeds and on a bad road the reaction of this spring is so great as to cause a rebound, and the gradually increasing momentum from each successive blow occasions very considerable oscillation.

This property has completely negatived its use for 4-wheeled carriages; but it is now used successfully under the 6-wheeled carriages on the North Woolwich branch, and there works to considerable advantage, permitting the wheels to adapt themselves freely to the curves of the road. The oscillation is there almost obviated, from the fact that the blows are received upon eight points, and that the reactive power of a blow on one of the eight points is not sufficient to disturb the inertia of the load. This spring has been and is now used to a very considerable extent on 6-wheeled carriages in Germany; but it is to be observed that the speed on the Continent is generally slower than in England.

A *Spiral Bearing Spring* is represented in fig. 6, Plate IV. The dimensions of these springs as used under the tenders of the Midland Railway were 9 in. height and 6 in. diameter, and they were made of $\frac{5}{8}$-in. round steel. Within this coil was fixed a second spiral of smaller diameter, coiled the reverse way to prevent the coils interfering. The action of a spiral spring is principally torsion of the steel bar through the angle A C B, and partly lateral deflection from the increase of diameter when the spring is com-

pressed. Practically the writer is not well acquainted with the use of these springs, but presumes that the following objections have been found in practice: the spring bears upon the sole-bar at one point, viz. over the centre of the axle-box, instead of at two points some 3 ft. apart. There is a much greater uncertainty in the degree of elasticity and supporting power than in flat springs composed of many plates, partly from the greater thickness of steel causing uncertainty in the tempering, and from the greater angular strain on the particles of the steel; the sudden blows experienced by railway springs requiring the thickness of the steel to be within a certain limit, say of $\frac{3}{8}$-in. or $\frac{1}{2}$-in.

Buffer and Draw Springs.—The ordinary Laminated Buffer and Draw Spring is 6 ft. $4\frac{1}{2}$-in. long, $5\frac{1}{16}$ in. thick, and 3 in. broad, consisting of 17 plates, the outside plates $\frac{3}{8}$-in. thick and the remainder $\frac{5}{16}$-in.; the camber when at rest being 13 in. The same principles of construction apply to this spring as to the laminated bearing spring in fig. 1. These springs are generally fixed in the centre of the carriage, sliding between four bars of iron, ordinarily termed the "buffer spring cradle." The ends are acted upon by the four buffer rods, and the draw bar is cottered to the centre of the spring. The same methods have been tried to obviate friction at the ends as have been already mentioned with respect to bearing springs, but these plans are now obsolete. In fixing the springs on carriages they are generally compressed one inch, and in wagons to the extent of about one-third of the stroke. The stroke of the buffer rod is limited to such an extent as will not deflect the spring beyond a straight line. The sustaining power of this spring is equal to about 2 tons 14 cwt., or equal in all including both ends of carriage to about $2\frac{3}{4}$ tons, developed through a stroke of 2 ft. As yet this method of buffing has not been surpassed or equalled, as none of the modern substitutes will give this moderate amount of resisting power developed through so great a space as 2 ft.; also the weight of the buffer springs being in the centre of the carriage, and the springs acted upon by long buffer rods, cause the action to be very steady.

The *Double Draw Springs*, with a check bar to limit the action within the straining point, make probably the only truly effective method yet adopted. It is to be observed that the springs when drawn home are limited in their action by the check bar AA, thus forming a continuous rigid draw bar (see fig. 7, Plate IV). The springs are each 2 ft. long, $3\frac{1}{16}$ in. thick, and 3 in. wide, consisting of 11 plates, of which 2 are $\frac{3}{8}$-in. thick and the remainder $\frac{5}{16}$-inch; the camber is $3\frac{1}{2}$ in. before fixing; the springs are each compressed $\frac{1}{2}$-in. in fixing. The method of fixing is the same as already described for the laminated buffer spring.

External Buffers. Within the last few years a considerable number of external buffers have been introduced, consisting of a cylinder and piston packed with nearly every available elastic substance, and practically varying only in the material of the packing.

De Bergue's Buffer Spring is packed with rings of vulcanised india-rubber; there are 4 rings $3\frac{1}{2}$ in. diameter, and $1\frac{1}{4}$ in. thickness each.

In the opinion of the writer this is the least effective of any yet produced, as the stroke is very short, and then only moderately developed under enormous pressure. It is questionable whether in the event of a collision, the train would not collapse and leave the rails, before the immense sustaining power of these springs was fully developed. This buffer has an apparent stroke of about 3 in.; but it appears that to drive up the pair of buffers $1\frac{1}{2}$ in. would require a force of 3 tons. By reference to the description of the ordinary laminated spring it will be observed that the stroke is 12 in. with a force of $2\frac{3}{4}$ tons; being 8 times the length of stroke, with a rather less force. It is also questionable whether the vulcanised india-rubber is of that imperishable nature originally supposed. The writer has had in his possession a considerable quantity of vulcanised elastic bands for papers, that have become completely rotten.

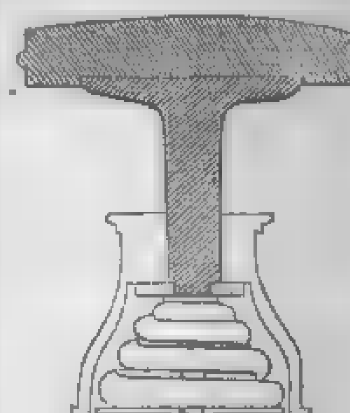
Todd's Cork Buffer is as nearly as possible the same as De Bergue's, excepting that the packing is cork; there are 5 plates of cork $7\frac{1}{4}$ in. diameter and $\frac{3}{4}$-in. thick each. This spring appears to be superior to De Bergue's inasmuch as the cork is more compressible than the vulcanised india-rubber, but it is questionable whether the cork is not liable to a permanent set.

Adams's Disc Buffer has the packing, consisting of 16 disc springs, made from flat circular plates of steel 8 in. diameter and $\frac{1}{8}$-in. thick, with a radiating piece AA, cut out to enable the plates to be pressed to a conical form (see fig. 8, Plate IV.) This buffer spring is superior to the foregoing inasmuch as the total amount of stroke is wholly developed, and the power can be properly adjusted by the thickness of the plates; the total length of stroke is $5\frac{1}{2}$ in.

Webster's Air Buffer exhibits considerable ingenuity, but is more complicated than the other plans. The air piston is 6 in. diameter, and the leather packing is distended by a vulcanised india-rubber ring; the length of stroke is 4 in. In the event of leakage during the stroke, the piston would not return to its original position, and to effect this a small spiral spring is employed which drives back the piston. A small valve admits air at the time that the piston is recovering its position to compensate for leakage during the stroke.

Spiral Buffer and Draw Springs are used to some extent, but they are liable to the same objections already described with reference to the spiral bearing springs.

Brown's Conical Spiral Spring Buffer appears to be the least objectionable of these (see the annexed woodcut). The resisting power is that of a spiral spring made in the form of a cone $7\frac{1}{2}$ in. diameter at the base, and the spring has the advantage of rotating at the point of the cone, thereby considerably easing the tendency to fracture or strain the particles of the steel; the steel is 1 in. wide and $\frac{3}{8}$-in. thick at the base of the conical spiral, and is tapered for the last three coils to $\frac{1}{4}$-in. diameter at the point of the cone. When driven home the spring forms a complete flat volute. The sustaining power of the spring is about equal for the space passed through to that of the ordinary laminated buffer spring, but with a shorter stroke, the length of stroke being only $3\frac{1}{2}$ inches, instead of 12 in. From its compactness and comparatively moderate price, it is in the writer's opinion, should the springs be found to stand their work, the most eligible of the external buffers; but yet far from equalling the result obtained by the use of the laminated buffer spring and buffer rods.



The whole of the cylinder and piston buffers are liable to the defect of the piston being guided through only a short length, and consequently they cannot work with the smoothness of the long buffer rod guided in several places. This more particularly applies in the event of an oblique blow upon the buffer.

In conclusion, it is suggested that it would be desirable for a correct table to be formed of the sizes, weight, sustaining power, and deflection of laminated bearing and buffing springs, as a uniform guide in their practical application.

Mr. Middleton remarked, that the conical spiral-spring buffer had been mentioned in the paper as the most advantageous of the external buffers in respect of the length of stroke, but that a still greater length of stroke was required; and he wished to mention one that he had introduced, consisting of a double-coned spiral spring, which had the advantage of giving a greater length of stroke, and he thought would form a very satisfactory buffer. They had been applied for the purpose of making a long buffer of 7 feet stroke, by using 6 of these springs, 4 in the middle and 1 at each end of the buffer rod.

Mr. Adams observed, that an objection to the double-coned spring would be that it was not free to revolve on its axis like the single-coned spring whilst it was being compressed, because it rested on the large base of the cone at each end, and the friction would be too great to allow of its revolving, but the single-coned spring had so little friction at the small end that it was capable of revolving when compressed. The strain on the steel was much increased if a spiral spring was prevented from revolving when compressed, and it was consequently more liable to break.

Mr. Fuller wished to state (for Mr. De Bergue in his absence), with respect to the vulcanised india-rubber in buffer springs, that upwards of 100,000 of the rings had been sent out, and many of them had been in use for two or three years; and as far as he had ascertained, the cases of failure had been very few indeed. In some cases where the material had been used for bearing springs, it had failed in consequence of not having a sufficient amount of bearing surface, but in the application to buffer springs he was not aware of any instance of failure excepting in a few cases where the rings had been over vulcanised.

Mr. Adams replied, that he had not had any experience of the durability of the vulcanised india-rubber applied to buffers, and he had therefore only stated the circumstance he was acquainted with of the bands for papers.

DETERIORATION OF RAILWAY AXLES.

(*With Engravings, Plate* IV.)

On the Deterioration of Railway Axles, &c. By Mr. J. E. McConnell.—(Paper read at the Institution of Mechanical Engineers.)

Having been requested at the last meeting to furnish further proofs of the change from the fibrous to the crystalline character produced in railway axles, and feeling convinced that a strict and careful examination of this important subject is a *necessity* in this age of railway practice, the inquiry has been resumed in the hope that the further information and experience gained may tend to a more perfect knowledge of the subject.

Before stating the results of the different experiments which have been made with the view of ascertaining the cause and extent of the change from the fibrous to the crystalline appearance in railway axle iron, it must be observed that in this, as in some other matters of controversy, it is most difficult to produce full and conclusive proof that the iron which is produced of a crystalline character was once fibrous, as we cannot by any experiment show the change visibly taking place; but surely it is fair and reasonable to admit the *fact* of a change, when we find railway axles when new, from the particular mode of manufacture, present through every part of their substance a tough, strong, fibrous appearance, yet, after several years' use, we find axles of the same description, owing to the various deteriorating causes in action, break short at the back of the wheel, and then present an appearance totally different from the original structure of the iron, as described above.

It has so happened, in strong confirmation of the views stated by the writer at the former meeting, that a very remarkable instance of this change was brought under his notice shortly after the discussion; and he thought the evidence which this case furnishes so important and conclusive (although produced without any design, and in the ordinary course of business), that the axle has been brought for the inspection of the present meeting.

This axle was fixed in cast-iron wheels, of the pattern in use on several lines of railway, having the H-form of spoke, and, as this wheel is perfectly rigid, experience has proved that the axles are much more liable to deterioration when working in these kind of wheels than in those wheels made partly of wood or other construction of wrought-iron, &c., which may have a certain amount of elasticity.

The axle now under consideration broke, in ordinary working, close at the back of the wheel, as is usually found; and the fractured ends, which are now produced to the meeting, afford the most distinct proof of the annular space which was stated on the former occasion to be observable all round the surface of the fracture; and this is not only short-grained and crystalline, but there is also, in the writer's opinion, an evident distinct separation to the extent of the annular space, which it would appear takes place some time before the final fracture, as if each successive blow, heavy or light, lateral or vertical, received or transmitted through the wheels, had each tended to destroy its proportion of cohesion of the previously crystallised substance of the axle at that particular place where the fracture occurs.

On receiving this axle in the workshops, with one wheel still attached, it was allowed by accident to fall a short distance from the wagon to the ground; and so brittle had it become next the wheel that the other end snapped off simply from the effect of the fall, and shows, as will be observed, a precisely similar appearance to the original fracture.

The writer was anxious to ascertain how far the theory which he held was correct, that the deterioration of the axle was principally local at that point (the back of the wheel), and for this purpose he caused the centre of the axle between the two fractures to be laid on supports, with the view of breaking it. A weight of cast-iron weighing 17 cwt. was then allowed to fall upon it through a space of 14 feet, but after several attempts it was found to make no impression upon this centre part of the axle towards effecting a fracture, although it was a frosty day, which would of course render the iron more brittle. Finding all efforts to break it by blows fruitless, the axle was then, in order to test its fibrous character, taken to the hydraulic press, and it has been bent to the form of the letter U, until the two ends met, without showing more than the slightest appearance of the skin of its surface breaking, as will be seen, proving still to be of a strong fibrous iron in the centre of the axle. See fig. 9, Plate IV.

Following up his proposition, the writer wishes to lay considerable stress on the view he previously stated, respecting the effect of the blows or vibrating action given through the wheels to the axle; he attributes the crystallisation of the axle at that point close behind the wheel, to the sudden stoppage or reaction of the vibratory wave at that place, owing to the check which it meets from the mass of matter consisting of the wheel, &c., presenting a break of surface, and acting more as an anvil, causing the vibration to react like a blow on the neck of the axle (the nearest weakest point), thereby destroying its fibrous character.

Cast-iron wheels, therefore, are objectionable from their rigidity and non-absorption of the lateral and vertical concussion with other strains formerly enumerated, received in course of working, and transmitted to be wholly expended on the axle; and the writer endeavoured to illustrate this by a comparative experiment with two different axles of the same description and age, one being fixed in cast-iron, and the other in wooden wheels, those known as the Pimlico make.

1st Experiment was made on the axle with wooden wheels placed horizontally resting upon the rails; a weight of 17 cwt. was allowed to fall through a distance of 13 ft. 3 in. upon the axle, immediately within the wheel, by which the axle was slightly bent at the point where the blow came, and a portion of the tyre resting on the rail was broken clear out. This experiment was repeated four times on the other end of the axle, which was bent but very slightly, and the wheel was rendered completely useless.

2nd Experiment was made upon the axle with cast-iron wheels, placed as in the former case, and the same weight was allowed to fall the same distance at the back of the wheel, when the effect of the first blow was to break the axle at the other end, at the back of the wheel; thus proving that in the former case the axle was saved from fracture by the wooden wheel absorbing its full share of the effect of the blow, and the tyre of the wheel breaking proved that in course of working it would receive a portion of the deteriorating forces tending to crystallise, the wheel acting like a cushion to soften the blows before they reached the axle; in the latter case the rail supporting the cast-iron wheel was fractured in three places.

A 3rd Experiment was tried with another axle with cast-iron wheels placed as before, and received four blows on each end of the axle within the wheels, which caused it to bend, but produced no fracture. This axle had not been much used, and was of a stronger fibrous character.

In order to ascertain the relative appearances of axles which had been in use, and determine the position of the crystalline change, both at the centre and outer surface of the axle, the writer caused four axles which had been condemned as too small from wear in the bearings, to have a groove cut in two cases on each side, to within an inch of the centre, and in the other two, grooved through to within an inch of the outer surface; these were split asunder with wedges, and their appearances will show that a certain change has been going on, and this is more observable in one end of the axle than the other, attributable, he believes, to the break being applied to the wheel which was on the end where the greatest crystalline change is visible.

He has made a number of other experiments in the presence of several of the members of the Institution, with the view of determining the effect produced on the fibre of iron by the cold hammering process. The following are the principal results:—

No. 1. A piece of ordinary bar-iron $2\frac{1}{4}$ inches wide and $1\frac{1}{8}$ inch thick, received 20 blows to nick it across, and was broken with 21 blows of a 14 lb. hammer, showing a fracture part fibrous and part crystalline.

No. 2. The same bar received 52 blows on one side, and 55 on the other, from the 14 lb. hammer, with 20 to nick it as before, and it broke with 14 blows, showing different layers of fibre and crystal.

No. 3. The same bar received 50 similar blows on each side as No. 2, but each blow on alternate sides successively, and 20 in nicking, and 9 blows broke it.

No. 4. The same bar was not cold-hammered, but received 20 blows in nicking, and required 28 blows to break it, showing a good fracture.

No. 5. Was a $\frac{7}{8}$-inch square bar, received 50 blows on each of two opposite sides, and 25 on each of the other sides, with 4 blows in nicking, and 5 broke it.

No. 6. Without any cold-hammering and the same bar, after receiving 4 blows to nick, required 6 to break it.

No. 7. The same as in the case of No. 6, had no cold-hammering, with 4 blows to nick it, and required 30 blows to break; in this case it was broken the flat way of the pile of the iron, but in No. 6 it was broken the edge way of the pile.

No. 8 Experiment was made on a shaft $3\frac{5}{8}$ inches diameter,

which was cold-hammered at one end, having received 204 blows on all sides from a $3\frac{1}{2}$ ton tilt hammer; 110 blows with a sledge hammer were given to nick this end all round which had been cold-hammered, and it required only 5 blows from a $3\frac{1}{2}$ ton hammer to break it; the other end which had not been cold-hammered, after receiving the same number of blows in nicking, required 78 blows under the $3\frac{1}{2}$ ton hammer to break it, thus proving the enormous amount of deterioration of the strength of the iron caused by the cold-hammering process.

No. 9. A piece of round iron $2\frac{5}{8}$ inches diameter which had two bearings turned (one at each end) $1\frac{7}{8}$ inch diameter by $2\frac{1}{4}$ inches long, was allowed to run at a considerable velocity for about an hour, with one end oiled and the other dry, the dry end being cooled with water repeatedly when it became hot; the iron was then experimented upon in order to determine by the different force required to break the end which had been injured by want of lubrication, the relative strength of each bearing, but such was the remarkably tough quality of this iron, that although it received 580 blows of a heavy sledge hammer in every possible way to break it in one direction (without being nicked), no fracture could be effected, but the iron seemed to be drawing out at the back of the journal on end, as will be seen by the meeting.

This last case is noticed in particular, as the following experiment of a similar character with an old axle of larger dimensions, shows in strong contrast the altered nature of similar iron from use on a railway, owing to the jar or vibrating action it has suffered.

In the 9th experiment a piece of new iron intended for part of an axle, although run dry and cooled with water, yet was so fibrous, having received no jar, that it resisted all effort to break it.

No. 10. Another experiment of a similar character was tried on an old axle which had been a long time in use, of the same kind of iron and manufacture as the bar in No. 9 experiment. This axle with the wheels on was run in its own bearings in a lathe at a velocity equal to 10 miles per hour for 5 hours; one journal was kept running dry, and when heated by the friction cooled with water, while the other journal was kept well lubricated with oil. When taken out, the journal which had been heated was broken with 12 blows of a hammer 22 lb. in weight, while the lubricated journal required 91 blows with the same hammer to break it, in both cases without being nicked; this appears satisfactorily to prove the injury to the axle which results from the practice of throwing cold water on the journal to cool it when it has become nearly red hot from want of proper lubrication.

In addition to various other experiments with the view of determining the change which is gradually going on in railway axles, and other iron liable to a jarring, vibrating motion, the writer would refer the meeting to a few samples of broken axles sent to him from various quarters, which, if proof were wanting, completely substantiate, in his opinion, the certainty of the crystalline change.

Before reading some of the communications received from other gentlemen containing their experience on the subject, he would first call attention to the two experiments which were tried in relation to the proportion and form of axle, in order to meet the objection raised at the former meeting, "that the slow pressure on the flanches of the wheel to discover where the axles were most exposed to the bending strain was not a faithful representation of what takes places in practice." The axle was fixed upright, so that the wheels were placed in such a position that the violent blow when the wheels of the carriage jarred upon the rail was fairly represented by the blow caused by the descent of a weight of 17 cwt. which was allowed to fall upon the edge of the wheel at A, from a height of $9\frac{1}{2}$ feet. It is most satisfactory to find that the curve into which the axle was bent, is quite in accordance with the former results, which were obtained by slow pressure applied at the same points, and establishes the rule of proportion of the axle therein stated. See figs. 10 and 11, Plate IV.

The following are some instances of tough fibrous wrought-iron being rendered brittle and breaking off quite square with a close-grained fracture from the effect of the concussion of very small blows rapidly repeated for a long period; the blows being very small in force compared to the strength of the iron. These specimens are from the machines for making button shanks, in Mr. Heaton's Mills, Birmingham. The hammer in these machines is about $2\frac{1}{4}$ lb. weight, and is lifted by a rod $\frac{5}{8}$-inch square, which has a pull upon it of about 12 lb. from the difference of leverage; the hammer strikes 120 blows per minute, but the cam that drives it acts only during one-fourth of its revolution, so that the velocity of the hammer is equal to four times the number of blows, or nearly 1000 changes of motion per minute. The lifting-rods always break with a close-grained short fracture, although made of the toughest and most fibrous iron that can be obtained, and they sometimes last only a few months; the rods break near to the end, which is fixed with a coupling, and the deterioration of the iron appears to be confined within a small portion, the iron remaining quite tough and fibrous within an inch of the fracture, as shown by the specimen, which has been bent double at that part. The hammer is snatched suddenly by the lifting-rod, and is pulled against a strong spring for the purpose of getting a quick recoil and a sharp blow of the hammer, much quicker than it would fall by gravity.

Another specimen from the same machines is the lever for pushing off the work from the machine when stamped; the lever is about $\frac{1}{4}$-inch square, made of the toughest wrought-iron, it is 9 inches long, and falls back against a stop at one-third of its length from the centre of motion at the bottom, being thrown back sharply by a spring, the total strain upon the lever varying from about 1 lb. to about 12 lb., according to the accidental circumstances in the working of the machine. These levers all break off quite short and close-grained within an inch of the part that strikes against the stop, but the iron continues quite fibrous and unchanged to within an inch of the point of fracture, as shown in the specimen. They were driven at the same speed as mentioned above, amounting to nearly the velocity of 1000 changes of motion per minute; but they broke so frequently, lasting sometimes only a few weeks, that it was determined at last to reduce the speed of the machines from 120 to about 100 blows per minute, and in consequence of this reduction in speed the levers are much less frequently broken, and last on the average about four times as long as before.

Communication from Mr. John Kekwick:—

"*The Holmes, Rotherham, 4th December*, 1849.

"I have been reading in the *Mechanics' Magazine* for last month a report of your able paper on railway axles, and I notice Mr. Robert Stephenson said that Mr. McConnell had expressed a strong opinion that a change took place from a *fibrous* structure to a *crystalline* one during the time of its being in use, and it would be satisfactory if an instance could be pointed out where this change had occurred owing to vibration or other treatment, &c. &c.

I think I can furnish an instance in proof of your opinion on this point:—In one of our forges we are daily in the habit of using a metal helve or hammer weighing about 4 tons, for the purpose of drawing large sizes of steel, and the shaft of this helve is 17 inches by 9 inches. Finding great inconvenience and danger from the breakage of *cast*-iron helves, we were induced to try a *wrought*-iron one 16 inches by 8 inches. After using this for several months, the shaft broke in two about the middle, and the fracture presented a crystalline appearance of 'short' cast-iron: we repaired the shaft, and in the course of a few months it again broke about the same place, and it again presented a similar granulated, cast-iron like, crystalline appearance throughout the face of the fracture. I attributed this change solely to the *vibration* and *jar* occasioned in the process of hammering steel, more particularly *cast-steel*."

Communication from Mr. Benjamin Gibbons:—

"*Shut End House, near Dudley, 15th January*, 1850.

"When the heavy cast-iron helves were used for drawing out bars, and the art of *chilling* iron was little understood, the nose or that part of the iron helve struck by the cam to lift it was protected by a wrought-iron plate well fitted, and this was secured by a large pin countersunk into it, and extended through a hole cast through the nose of the helve, and screwed as fast as possible on the upper side. The very best and *most fibrous iron* (ascertained to be so by previous breaking) was always selected, and yet when the pin broke by the repeated shocks it had to sustain (about 90 times per minute), it always broke with a large bright grain, *without the least trace of fibre*. This was so regularly the case that I never knew a pin last for many months.

Another instance was in a fly-wheel where wrought-iron arms were used instead of cast-iron, for the purpose of throwing the weight to the outer circumference, and this wheel was applied to a forge-hammer engine. It worked well for a time till the arms got loose in the cast-iron rim, and then a violent shock was received every time the cam struck the helve; after some time, the arms began to break one after the other, and though the iron was of the toughest description originally, it was found that any part broken was of a bright crystalline grain.

The pins of shears for cutting down large cold bars sustain violent shocks; they perpetually break with the same bright grain, though made of the toughest iron. Also the iron arms of common carts always break with that grain from the same apparent cause.

I have taken iron of this bright crystalline character which I had previously known to be fibrous, and by drawing it down a little at a proper heat have never failed to restore the fibrous texture of the iron."

The practical suggestions derivable from the foregoing experi-

ments and inquiries, which are confirmed by all the writer's previous experience and information, are—

1st. That the axles of all railway engines, carriages, and vehicles should be made of the best ascertained quality of iron for the purpose, both tough and strong, and of uniform clean fibrous texture.

2nd. The proportion of an axle in all parts to be determined from sound experience and calculation; the load it has to carry, the speed at which it is run, and the description of wheel in which it is placed, and strains to which it is liable in working from curves or inequalities of the road, or other deteriorating causes, being fully considered.

3rd. That previous to any axle being allowed to run on any line, the maker's name should be legibly marked thereon and the date of manufacture, and also when it was first put to work. It is of course manifestly impracticable to record the number of miles run; but as all railway stock in a general way is worked nearly uniform, the above particulars would afford the necessary data to guide the opinion which may be formed of the age beyond which limit the iron becomes comparatively unsafe.

4th. That it be part of the duty of the proper officer to see that all axles are working in good condition and receiving careful treatment.

5th. The next point the writer would press is, that all in whose power is the opportunity for registering facts in connection with railway axles, should by this, or some recognised scientific Institution, be requested to note and carefully collect their information on all points, in order that a certain average result for the guidance and benefit of all interested may be arrived at.

6th. That attention should be given to ascertain the description and working condition of wheels which in all points cause the least deteriorating effects on the axle; and for this he proposes to produce some further experiments and also results from practice.

7th. That the quality of lubrication and description of bearings used should also be considered; and for this he also proposes to give a paper to the Institution, with the results of experiments and experience.

It is obviously of most material advantage to all who are connected with or have the management of machinery, whether for railway, manufacturing, or mining purposes, to have their attention directed to the phenomena bearing upon the nature, use, stability, and durability of the iron or other material of which that machinery is constructed; as it must be manifest that we must first obtain a clear knowledge of the best quality, the best form, and the best treatment necessary to select and prepare it for use, and to preserve it from any deteriorating causes as far as possible, in order to obtain the greatest safety, efficiency, and economy in working the machinery for the purpose it is intended to effect.

With the above views kept prominently before them in all their inquiries in this as well as in other branches of practical research in developing improvements of commercial utility, the members of this Institution, from their different positions, with large and varied opportunities, will be enabled to effect great good; they will assist the progress of useful mechanical inventions, and entitle themselves to the respect and gratitude of all classes, as being the means of producing and encouraging lasting and substantial advantages to the commercial and manufacturing interests of the country.

Remarks made at the Meeting after the Reading of the foregoing Paper.

The Chairman (Mr. McConnell) remarked, that it was much to be regretted that their President, who took a great interest in the subject, was absent, and perhaps it would be well not to conclude the investigation that evening, in order to afford him an opportunity of being present.

Mr. Cowper inquired with reference to the broken axle exhibited, whether it had been nicked to a square shoulder and broken to test the quality of the iron, or whether it had only been bent by pressure?

The Chairman replied, that the axle was broken at one end whilst running on the railway, and was broken off short at the other end by falling to the ground; and then in order to see whether the crystallisation was local or otherwise, it was afterwards bent in the centre by three or four blows from a weight of 17 cwt., falling upon it, without the axle being nicked, and it was then doubled up by the hydraulic press, but it did not show any appearance of breaking.

Mr. Wright observed, that the fracture was at a very deep square shoulder, and a great deal of the appearance round the fracture might be the result of the shoulder.

The Chairman replied, that this to a certain extent might be the case, but even without the shoulder there seemed to be an annular crystalline space going on forming.

Mr. Walter Williams expressed his full concurrence in the views stated by Mr. Gibbons in his communication, which were founded on very long experience. He could also speak from the experience of many years, that he had invariably found that iron much used as axles broke in the manner described by the Chairman. He was therefore quite satisfied that a change takes place in the structure of iron, and was rather surprised that a different opinion was entertained, because he had observed hundreds of instances where after having produced a good tough fibrous iron, yet after hammering it had broken crystalline. But to show how well it was known that iron was affected in structure, he would mention that in making iron for particular purposes it was desirable to have it of very close fibre, and it was customary to throw the hot iron into a water bosh in the state in which it came from the rolls, and that injured its fibre. The object in thus dealing with the iron was to clean it, and when next put through the rolls its fibrous character was restored; hence he was of opinion that in the case of axles deteriorated by wear their fibrous character might be restored by drawing down hot, for there was no doubt it was the action of the wheels which made the change.

Mr. Hodge considered the subject as one of great importance, and suggested that the discussion should be deferred until after the members had been furnished with a copy of the paper and the experiments, with such diagrams as were necessary for their illustration. So important was the question which presented itself with reference to changes in the structure of iron, that it had occupied the attention of the American Institute for two sessions, and he thought that this Institution should not allow the subject to pass without a long and careful consideration, because it was necessary to have regard to the various circumstances under which the iron was manufactured, and the particular character of the iron itself.

Mr. Henry Smith, in reference to his promise at the last meeting to furnish some results at the present meeting, observed that the experiments on cold-hammered iron, which were described in Mr. McConnell's paper, had been tried at his works, and he fully concurred in all that Mr. McConnell had said with reference to them.

Mr. P. R. Jackson inquired which class of iron the chairman considered best for railway axles—malleable iron or steel? For his own part, when he required great strength he employed good steel, and found that answer the best.

The Chairman, in reply, repeated the first practical deduction contained in his paper—viz., "that the axles of all railway engines, carriages, and vehicles, should be made of the best ascertained quality of iron for the purpose, both tough and strong, and of uniform clean fibrous texture." That was his opinion with reference to the quality of iron to be employed; and he thought the Institution would be departing from its province were it to consider any particular district or manufacture. They were now treating of the *deterioration of railway axles*, and the question to be decided by proofs adduced to the members was whether they underwent such a change as from fibrous to crystalline iron; that question being determined, they might then not only consider the quality of iron, but the form of railway axles most advantageous to be adopted.

Mr. Hodge observed, that when steel was employed it was in order to produce stiffness and not to resist torsion; he did not think that the mere imparting of carbon to iron would give it the properties required for the present purpose.

Mr. Slate doubted whether the term fibrous, as applied to iron, properly described the state or condition of the material to which it referred. He could understand a fibre of cotton or wool, or other such material, but in the case of fibrous iron, as it was termed, they found a series of small crystals united longitudinally, giving the appearance of fibre; and when that changed to larger crystals the peculiar cohesion seemed to be destroyed, and the whole became a conglomerate mass without any appearance of fibre.

Mr. Cowper said, it appeared to him that fibre in iron was composed of the separate particles of iron existing in the puddling furnace of different sizes, and that these were afterwards elongated in the process of forging and rolling, so that a number of long particles were obtained lying near to each other, though there was not perfect contact, owing to the interlying cinder. Crystalline iron was that in which the particles assumed any other form than the elongated form. All iron contained a portion of cinder or silicate of iron, which was more or less squeezed out in the process of forging and rolling.

Mr. Hodge remarked, that to arrive at any true results as to the structure of iron it would be necessary to call in the aid of the microscope, to examine the fibrous and crystalline structure.

Mr. Walter Williams adverted to the well-known fact that the continued working of machinery, such for instance as the crank pins of engines, destroyed the fibrous structure of the iron and made them crystalline.

Mr. Cowper remarked, that it was his opinion that iron could not become crystallised unless it was hammered or so strained by force as to alter its form and produce a permanent set or change of form; he did not think however that an iron railway axle became crystallised from the action of the concussions of the wheels; because he did not think that the effect produced was equivalent to cold-hammering; he thought a fair experiment would be to turn a square shoulder in the centre part of the broken axle which had been

bent up by pressure, and then to break it with a nick at the shoulder, and see if it broke with a fibrous or crystalline fracture, for it was well known that by nicking iron it would break more crystalline.

Mr. HODGE illustrated the subject by reference to the effect produced upon the journal of a picker shaft in a cotton mill, at Lowell in America, where in order to produce stiffness a shaft of cast steel was introduced, but it frequently broke off at the journal, particularly when there was a very tight belt on the drum. A collar of cast-iron $1\frac{1}{2}$ inch thick was then shrunk on the journal working in a brass bearing, and it then worked well. He merely adduced this fact to show that the friction caused by high velocity produces a change in the molecular structure of iron.

Mr. HOSY did not think that from the mere appearance of the sectional fracture they could exactly determine the molecular change. They would recollect that Mr. Stephenson adverted to some experiments by Mr. Brunel, where from the mode of producing the fracture the same bar of iron gave out different results; these experiments were perhaps conducted on too small a scale to furnish undeniable results, but he thought it quite possible that the same bar of iron should exhibit different results when twisted slowly in a vice or struck by a smart blow; in the one case the fracture might be crystalline, but fibrous in the other.

A Member said that he had tried an experiment with very tough charcoal iron; he merely attached it to the head of a tilt hammer, which went about 300 strokes per minute, and after a few weeks it broke off brittle without any blow, although the iron was at first as tough as it could be made; and this was attributed only to the jarring.

Mr. HODGE observed, that this was quite analogous to the results given in the report of the Commissioners on the experiments with reference to the duration of wire bridges in France, that the effect was produced by the constant vibration or jarring between the particles of the iron.

Mr. WILLIAM SMITH said, that he produced two specimens of ordinary puddled-bar iron $1\frac{1}{2}$ in. square, on which he had tried the effect of hammering; the first piece was broken off from the bar by 22 blows of a 14 lb. hammer, the bar having been nicked, and the fracture was very fibrous; the second piece was 7 in. length cut off from the same bar next to the first piece, and he set it on an anvil and struck it 20 blows on the end, and it was then nicked in the middle and broke off with a single light blow, and showed a square crystalline fracture; another piece was then broken off the same end of the bar as the first piece, to ascertain if the quality of iron in the bar was the same, and it required 21 blows to break it, and was similar in the fracture to the first piece.

Mr. MIDDLETON remarked, that in taking off the tyres from the driving wheels of an engine he observed that the bolts were quite crystalline; he was quite satisfied there was a change. And with regard to the hammering which took place on the rails, in his opinion, it was quite sufficient to cause the change observed in railway axles.

Mr. HEATON said, he fully concurred in all that had been said in favour of a change being effected in the structure of iron. He considered the change was generally confined to some particular part, and the rest of the iron was not injured; in his machine for flattening button shanks, which gave a blow of about 12 lb. (mentioned in Mr. McConnell's paper), the constant action had the effect of breaking the levers, which showed a crystalline fracture, although within half-an-inch from the part so broken the iron continued unchanged and quite fibrous. The same was observable in the cross pins of corn-spindles which frequently broke in a few weeks' wear; and he did not know which lasted the longest, steel or iron, but he thought good scrap iron would last as long as a piece of steel, but it would not last half the time if subjected to cold swaging. In the example he produced of broken cross pins, the fracture showed a vertical division, because the strain was only at each side; but in the case of a railway axle the fracture showed a circular space in the centre, because the strain was all round the axle on all sides in succession.

The further consideration of the subject was then adjourned to the next meeting, and the Chairman said, he hoped the members would come forward with all the information they could collect which bore upon a question of such importance; and for his own part he would take every opportunity of trying further experiments and collecting facts with reference to it.

Coating Ships' Bottoms.—A patent has recently been granted to Messrs. A. Yule and J. Chanter, for improvements in coating ships' bottoms with one or other of the following compositions:—First, 8 to 10 parts of bullock's-gall, 30 lb. of carbonate of iron or plumbago reduced to a fine powder, and mixed together to form a paste, to which 4 gallons of salt water are to be added to bring the whole to a proper consistence. [What relation is there between parts and pounds?]—Second, 30 lb. of carbonate of iron or plumbago in powder, 3 lb. of white arsenic, $2\frac{1}{2}$ gallons of coal tar, naphtha, or spirits of turpentine, and from 12 to 14 lb. of Stockholm tar.—Third, 10 lb. of carbonate of iron or plumbago in powder, and 1 lb. of white arsenic, to which Russian tallow is added, with the assistance of heat to incorporate the whole. This composition is to be applied hot, and rubbed over with the dry powder.

DWELLINGS OF THE LABOURING CLASSES.*

On the Dwellings of the Labouring Classes. By HENRY ROBERTS, Esq.—(Paper read at the Royal Institute of British Architects, Earl de Grey, K.G., President, in the Chair).

The subject to be now submitted to the consideration of the Institute of British Architects is one to which their special attention has not been previously invited, although it was incidentally alluded to by my friend, Mr. Smirke, in the course of the last session.

Much has lately been said and written on the dwellings of the labouring classes; our illustrious patron, the Prince Consort, has emphatically shown that he feels deeply interested in this subject, and has publicly announced that "these feelings are entirely and warmly shared by her Majesty the Queen," our most gracious patroness. Still it is probable that but few members of the Institute have given any special attention to those details which will be brought under your notice; and certainly a yet more limited number have been professionally engaged in a field of labour, which apparently offers little scope for scientific skill, and but few attractive points to an artist's eye. Such was my own case when, between five and six years since, I undertook the duties of Honorary Architect to the Society for Improving the Condition of the Labouring Classes, to whose operations in this department your attention will be hereafter invited.

There appear to be many reasons which, in an especial manner, commend this subject to the consideration of the architect, besides those which give it so strong a claim on the serious attention of the philanthropist and political economist. A moment's reflection must show that the highest achievements of architecture are accomplished through the instrumentality of the working classes, whose skill and persevering industry conduce as much to the fame of the Architect as the steady valour of the soldier does to weave the crown of victory around the brow of his triumphant General.

We shall not enter into a lengthened detail of the present state of the dwellings in which a very numerous body of the labouring classes are lodged. Personal observations most fully confirm what has been stated over and over again as to the magnitude and wide extent of the wretchedness resulting from their actual condition, arising, as it does, from the want of all those arrangements which are calculated to promote the comfort and moral training of a well-ordered family, as well as the utter absence of proper ventilation, efficient drainage, and a good supply of water; together with a system of overcrowding that would not be tolerated for the domestic animal in the farm-yard, the stable, or even the dog-kennel. One example may suffice. About four years since, with the desire to obtain ocular demonstration as to the actual existence of such a state of things, I visited with a friend several houses in the immediate neighbourhood of the Model Lodging House, George-street, Bloomsbury, to be hereafter described. In one of these houses was a room about 22 feet by 16 feet, the ceiling of which could be easily touched with the hand, without any ventilation, excepting through some half-patched broken squares of glass; here were constantly lodging from forty to sixty human beings, men, women, and children, besides dogs and cats. Further detail it is unnecessary to describe; their very recital would disgust you.

If it be said that the remarks just made can alone apply to a metropolitan St. Giles's, or to Saffron-hill, a reference to the valuable reports of the Health-of-Towns' Commission, or to the more recent and graphic descriptions in the columns of the *Morning Chronicle*, will abundantly show that our provincial towns, our rural villages, and even many of the picturesque cottages which so much enliven the landscape of Great Britain, form no exception to the wretched condition of a large proportion of the dwellings tenanted by our labouring peasantry, artisans, and mechanics. In a provincial town, I lately entered one of three cottages approached by a passage 2 ft. 6 in. wide, common to the whole of them; in a ground-floor room, 10 ft. 6 in. by 8 ft. and 5 ft. 10 in. high, with a triangular loft in the sloping roof, were lodged a husband, wife, and five children. The out-buildings common to these cottages I forbear to describe. Yet this is an underdrawn picture of the domiciliary wretchedness which many a dwelling in England, with its boasted civilisation, refinement, and wealth, presents. Some have only one room, occupied by a great number of inmates; some have three or four rooms, each occupied by a distinct and often numerous family; in some cottages, one or more

* This Paper has been printed in full in a pamphlet, together with several wood engravings and lithographs of Dwellings for the Labouring Classes, which is well worthy of perusal. It is published at 2s. 6d., for the benefit of the Society.

lodgers occupy the same apartment with the family, regardless of age and sex.

The practical view of the improvement of the dwellings of the labouring classes which it is desired to bring under consideration, will be most conveniently taken by first pointing out the general principles applicable as well in towns as in the country, and afterwards by considering these two descriptions of dwellings separately.

The most humble abodes, whether in a town or in the country, in order to be healthy, must be dry and well ventilated; to secure the former, it is essential that due attention be given to the situation or locality, to the foundation, and to the drainage, as well as to the material of which the external walls and roof are constructed. To secure ventilation, there must be a free circulation of air; a sufficient number and size of openings, and adequate height of the rooms, which I should fix at not less than 7 ft. 6 in. to 8 feet.; in town buildings I have allowed 9 feet from floor to floor. The area of the apartments should be in proportion to the probable number of occupants; where intended for families, the living room ought not to contain less than 140 feet to 150 feet superficial, and the parents' bed-room should measure at least about 100 feet superficial; in the latter it is of importance, as a provision for sickness, that there should be a fireplace. In every room an opening for the escape of vitiated air ought to be made near the ceiling, especially in the smaller bed-rooms for children, where there is no fireplace. An entirely satisfactory system of ventilation, applicable to small apartments—by means of which the vitiated air shall be removed, and an adequate supply of fresh air be introduced, without causing any perceptible current,—appears to be still a desideratum. My experience is certainly unfavourable to the *indiscriminate* use of chimney valves fixed in the ordinary manner. In some cases, they answer perfectly; in others, it is almost impracticable to prevent the ingress of smoke through the aperture; on this account I prefer, where practicable, carrying up for some height an independent ventilating flue, which may be 9 inches by 4 inches or even smaller, and ultimately open into the chimney flue, or into the external air if there be no chimney flue from the apartment. The most simple and economical ventilator for the admission of external air which I have tried is fixing in an aperture behind an air brick an iron frame fitted with a sheet of perforated zinc, and having an iron plate hung to close it with a rack. Perforated ventilating glass and Bailie's sliding ventilators are both valuable inventions.

For the comfort and health of the inmates of every tenement, the protection afforded by an internal lobby or close porch is of importance, as well as the relative position of the doors and fireplaces to the living room, which should be so arranged that there may be at least one snug corner free from draught. Where casement windows are used, the great difficulty which is found in the lower class of buildings of rendering them weather-tight, renders it desirable that they should invariably be made to open outwards, and be properly secured by stay-bar fastenings. Zinc I have found the most satisfactory material for casements, and if the quarries are well proportioned and not too large, their effect differs very little from that of lead.

In illustrating the general principles to be advocated as applicable, particularly to town buildings, it will be convenient to refer to the dwellings erected by the Society for Improving the Condition of the Labouring Classes. This Society was established in 1844, under the patronage of her Majesty the Queen, with the Prince Consort as its illustrious President. Influenced by the philantrophic principles so powerfully advocated by their noble chairman, Lord Ashley, and stimulated by his example, the committee of this Society undertook, as one most important branch of their labours, "to arrange and execute Plans as Models for the Improvement of the Dwellings of the Labouring Classes, both in the Metropolis and in the Manufacturing and Agricultural Districts." For the past five years they have been steadily engaged in presenting successive models of improved dwellings adapted to the various circumstances of the industrial classes.

With these views, the Society proceeded to build between Gray's-inn-road and the Lower-road, Pentonville, near Bagnigge-wells, their first set of model dwellings on the only eligible site of ground then offered.

1. Nine families occupy each an entire house, with a living-room on the ground floor, having an inclosed recess, or closet, large enough to receive beds for the youths of the family, two bed-rooms on the upper-floor, and a small yard at the back: these houses are let at a rent of six shillings per week.

2. The remaining fourteen families are distributed in seven houses, each family occupying a floor of two rooms, with all requisite conveniences; and as the apartments on the upper floor are approached through an outer door distinct from that belonging to the lower floor, their respective occupants are thus kept entirely separate, and each floor is virtually a distinct dwelling. The rent paid by each family is three shillings and sixpence per week.

A *wash-house*, with drying ground, is provided for the occasional use of the tenants of these houses, at a small charge.

3. The centre building on the east side will accommodate thirty widows or females of an advanced age, each having a room, with the use of a wash-house common to them all. The rent paid for each room is one shilling and sixpence per week. Subsequently it has been thought by the Committee that this rent should have been fixed at two shillings per week.

Where space will admit of it, some modification in the arrangement of houses built after this general model would be desirable. The Society has published a plan in which these alterations are embraced.

Encouraged by the immediate occupation of their first set of buildings, and the approval of the public manifested by liberal contributions to their funds, the Society next proceeded to exhibit a model of an improved lodging-house for working men.

To show the practicability of effecting a great improvement in the existing lodging-houses, the Society began by taking three lodging-houses in one of the worst neighbourhoods in London—viz., Charles-street, Drury-lane. These they completely renovated and converted into one house, which has been fitted up with clean and wholesome beds, and all other appurtenances requisite for the health and comfort of eighty-two working men, who pay at the same rate as is charged for the wretched accommodation afforded in ordinary lodging-houses—viz., fourpence per night, or two shillings per week, and cheerfully conform to the regulations of the establishment. In a financial point of view, this experiment is amply remunerative to the Society.

But, however valuable as an experiment, and calculated as a stimulant to produce highly beneficial results, the house in Charles-street cannot be considered as the model of what a lodging-house ought to be. The Committee therefore purchased a piece of freehold ground in George-street, St. Giles's, surrounded by other lodging-houses, and have built on it a model lodging-house for 104 working men.

The Plans fully describe the arrangement of the several floors; and the fitting-up of the principal apartments may be thus briefly stated:—The kitchen and wash-house are furnished with every requisite and appropriate convenience; the bath is supplied with hot and cold water; the pantry-hatch provides a secure and separate well-ventilated safe for the food of each inmate. In the pay-office, under care of the superintendent, is a small, well-selected library, for the use of the lodgers. The coffee, or common room, 33 feet long, 22 feet wide, and 10 ft. 9 in. high, is paved with white tiles, laid on brick arches, and on each side are two rows of elm tables, with seats; at the fire-place is a constant supply of hot water, and above it are the rules of the establishment. The staircase, which occupies the centre of the building, is of stone. The dormitories, eight in number, 10 feet high, are subdivided with moveable wood partitions 6 ft. 9 in. high; each compartment, enclosed by its own door, is fitted up with a bed, chair, and clothes-box. In addition to the ventilation secured by means of a thorough draught, a shaft is carried up at the end of every room, the ventilation through it being assisted by the introduction of gas which lights the apartment. A ventilating shaft is also carried up the staircase for the supply of fresh air to the dormitories, with a provision for warming it if required. The washing closets on each floor are fitted up with slate, having japanned iron basins, and water laid on.

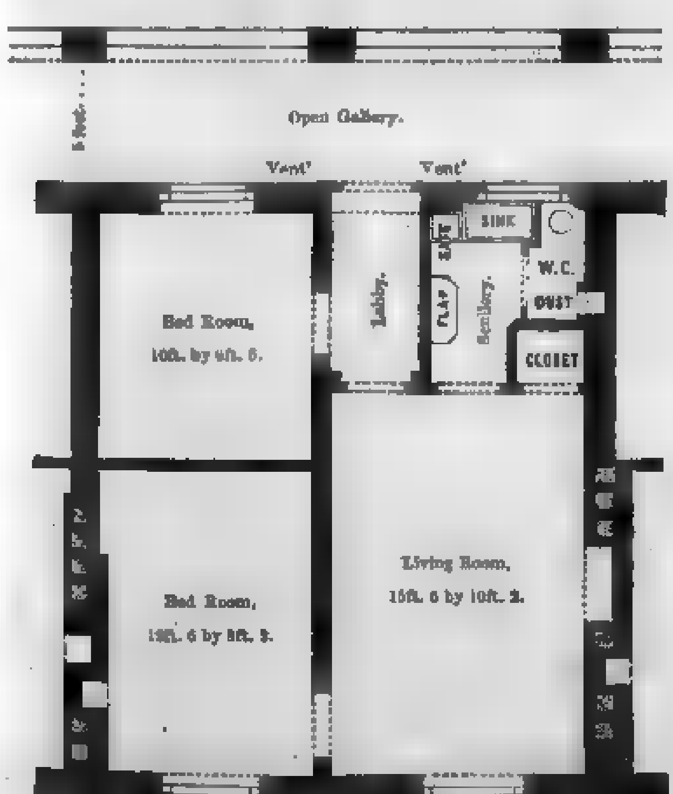
The Society has recently fitted up in Hatton-garden a lodging-house for fifty-seven women, which may be referred to as the completest example of the adaptation and arrangement of an old house with all the conveniences desirable in such an establishment.

The question of lodging a large number of families in one lofty pile of building has been the subject of much discussion, and in reference to it the most contradictory opinions were stated before the Health-of-Towns' Commission. Some thought it the best adapted and most economical plan to provide in one house, with a common staircase and internal passages, sufficient rooms for lodging a considerable number of families, giving them the use of a kitchen, wash-house, and other necessary conveniences, in common; others objected that such an arrangement would lead to endless contentions, and be attended with much evil in cases of contagious disease. It must be obvious that in many localities where labourers' dwellings are indispensable, it is impossible to provide them with isolated and altogether independent tenements; and therefore,

though modified by local and other circumstances, it will be found the general practice in Great Britain, as well as in the large continental towns, for several families of the working classes to reside in one house.

The important point, then, for consideration, is, in what manner can the advantages of this economical arrangement be retained, without the serious practical evils which have been referred to?

In providing for the accommodation of a large number of families in one pile of building, a leading feature of the plan should be the preservation of the domestic privacy and independence of each distinct family, and the disconnection of their apartments, so as effectually to prevent the communication of contagious diseases. This is accomplished in the model houses built in Streatham-street, Bloomsbury, by dispensing altogether with separate staircases, and other internal communications between the different stories, and by adopting one common open staircase leading into galleries or corridors, open on one side to a spacious quadrangle, and on the other side having the outer doors of the several tenements, the rooms of which are protected from draught by a small entrance lobby. The galleries are supported next the quadrangle by a series of arcades, each embracing two stories in height; and the slate floors of the intermediate galleries rest on iron beams, which also carry the inclosure railing. The tenements being thus rendered separate dwellings, and having fewer than seven windows in each, it is confidently submitted are not liable to the window-tax—which, in a financial point of view, is a consideration of much importance—a saving of at least between seventy and eighty pounds per annum being thus effected on the entire range of buildings.



PLAN OF ONE OF THE TENEMENTS.

The plan at a large scale exhibits one tenement or set of apartments with their appropriate fittings, which comprise all the conveniences requisite for a well-ordered family, and include, in addition to the bed-rooms, a provision for an inclosed turn-up bed in a closet out of the living-room.

The nature of the foundation rendering excavation to a considerable depth indispensable, a basement story has been formed, with a range of well-lighted and ventilated workshops.

The floors and roofs of these buildings are rendered fire-proof by arching with hollow tiles or bricks slightly wedge-shaped. They are 6 inches deep, 4 inches wide on the top part, 9 inches long, $\frac{7}{8}$ths to 1 inch thick; the rise of the arches is from $\frac{3}{4}$-inch to 1 inch per foot on the span, and they are set in Portland cement in the proportion of one part cement to two parts sharp sand, the tiles being well wetted before being used.

The arrangement of the building is such as to render the floor and roof arches a continual series of abutments to each other, excepting at the extremities, where they are tied in with $\frac{7}{8}$-inch iron rods, secured to stone or cast-iron springers. The roof is levelled with concrete, and asphalted. The floors of the bed-rooms are boarded on joists 2 inch square, cut out 1 inch on the back of the arch, and secured to two sleepers; the remainder of the floors are in Portland cement, excepting the basement, which is of metallic lava.

The extra cost of rendering this building fire-proof, as well as preventing the communication of sound, and all percolation of water between the several floors, by means of the tile arches, beyond the cost of construction with the ordinary combustible floors and roof, as ascertained by comparative tenders, do not exceed about 12s. per cent. on the contract for the entire pile of building, which is 7370*l*.; and, in all probability, when a regular demand arises for roof and floor arch-tiles, they will be supplied at such a price as to allow of their use without any extra cost.

The Metropolitan Association for Improving the Dwellings of the Industrious Classes was incorporated by royal charter in October, 1845, and their first range of dwellings, built in the Old Pancras-road, for the accommodation of 110 families, was opened for reception of the tenants early in 1848. These buildings, from the designs of Mr. Moffet, present an extended and imposing front of about 226 feet, with advancing wings, and are five stories high. The subdivision into distinct double-houses, with a central stone staircase to each, is similar to that of the Birkenhead buildings. They are not fire-proof, but have the advantage of larger-sized apartments, and unobstructed light and air. The internal staircase arrangement involves them equally in the heavy charge of window-tax, which, on the whole pile of buildings, amounts to about 150*l*. per annum. These buildings have been constantly occupied since their completion, and the most gratifying evidence has been given of the change produced in the health and comfort of the tenants, by their improved and salubrious dwellings.

The second undertaking of the Metropolitan Society has been the building in Spitalfields of a lodging-house for 234 single men, with dormitories arranged on a similar plan to those in the George-street, Bloomsbury, lodging-houses, opened in 1847. The living-room accommodation is more extensive and costly, as it comprises a coffee-room 45 feet by 35 feet, a kitchen 40 feet by 21 ft. 9 in., a lecture-room 35 feet by 21 ft. 9 in., and a reading-room 25 feet by 21 ft. 9 in. This building is just completed from the designs of Mr. W. Beck. The charge for each lodger has been fixed at 3*s*. per week, whilst that in George-street, Bloomsbury, is only 2*s*. 4*d*. per week; it remains to be seen whether the extra payment beyond 4*d*. per night, the usual charge for lodging for single men, will be paid for such increased accommodation. It may also be questionable how far the class of men for whom lodgings in such a neighbourhood are chiefly needed, will be really benefited by the luxuries here provided, and which but few men in full employment can have much time for enjoying. It should, however, be observed, that the proximity of this establishment to the spacious range of dwellings for families, building by the same Association, affords the opportunity of appropriating to the use of the occupants of those dwellings, during certain portions of the day, some of the accommodation afforded in this building, and thus turning to good account what might otherwise be surplus accommodation.

The internal plan of these dwellings for families is similar in general disposition to those in the Old Pancras-road, the relative position of the door and fire-places in the living-rooms is better than in the latter buildings, but the position of the entrance under the centre of the staircase, from apparent want of height, is unsatisfactory.

Besides the new buildings to which reference has been made, the spirit of improvement has in several places been manifested by the re-modelling of old buildings, and fitting them up as near as circumstances will admit on an improved and sanitary plan, so as to render them healthy and comfortable abodes. That improvements of this description might be effected to a very great extent, with immense advantage to the working classes, and a handsome remunerative return to those who undertake them with judgment, and who do not shrink from the trouble which they involve, the experience of the Society for Improving the Condition of the Labouring Classes has clearly demonstrated.

In adapting and fitting up old buildings, as well as in erecting

new ones, experience has taught the importance of a judicious selection of the locality, which should not be too far removed from the daily occupation of the expected tenants, nor should they be in close contact with the residences of a much higher class in society.

In reference to new buildings for the labouring classes, the most rigid economy of arrangement, consistent with accommodation sufficiently spacious to be convenient and healthy, and the utmost attention to cheapness of construction, consistent with durability and comfort, are essential elements of a really good and suitable plan. The architect should bear in mind that the rents which the working classes usually pay, though exorbitantly high for the wretched accommodation afforded them, will only just yield a fair return for the outlay on buildings constructed for their express use, and fitted up with all the conveniences which it is desirable they should possess. Any expenditure on unnecessary accommodation, which involves an increase of rent beyond that usually paid by the occupants of such a class of dwellings, appears to be at least hazardous, and may jeopardise the whole or a portion of the interest to be fairly expected from the investment.

The remaining branch of my subject, on which I have now to speak more particularly, is that of labourers' dwellings in agricultural or country districts.

The attention of landed proprietors has often been directed to the necessity for the improvement of labourers' cottages, and in not a few instances the entire aspect of a village and neighbourhood has in this respect been completely changed by the well-directed efforts of a single landlord. Illustrations might be drawn from the example set by many noble and wealthy proprietors: in the first instance I will cite a case which shows how, with comparatively limited means, much good may in this way be effected. In the recently published memoir of John Howard, it is recorded that when he first went to reside at Cardington, in Bedfordshire, about 1756, he found it one of the most miserable villages which could have been pointed out on the map of England. Its peasant inhabitants were wretchedly poor, ignorant, vicious, turbulent, dirty. With his characteristic energy and earnestness, Howard set himself, within the sphere of his own competence and influence, to ameliorate their condition both in a worldly and spiritual sense. Beginning with his own estate, he saw that the huts in which his tenantry, like all others of their class, were huddled together, were dirty, ill-built, ill-drained, imperfectly lighted and watered, and altogether so badly conditioned and unhealthy, as to be totally unfit for the residence of human beings. He resolved to begin his work at the true starting point, by first aiming to improve their physical condition—to supply them with the means of comfort; attaching them thus to their own fireside, the great centre of all pure feelings and sound morals—to foster and develope in them a relish for simple domestic enjoyments.

The first step which he took in furtherance of these objects was obviously a wise one, that of rendering the *homes* of the poor dwellings fit for self-respecting men. This must indeed be the starting point of every true social and industrial reformation.

Your attention must now be directed to the very important communication on the dwellings for agricultural labourers made by his grace the Duke of Bedford through the Royal Agricultural Society, in a letter addressed to the Earl of Chichester, President of that Society, for the past year; and I feel assured that it will not be deemed unsuitable for me to quote such high authority on the obligations of landed proprietors.

I have lately had the pleasure of examining a considerable number of the new cottages recently built, with judgment and great care, on the Duke's Bedfordshire property, which already exceed 100; and it is the intention of his grace gradually to continue the re-building of decayed tenements in the same county, until 300 more are erected. The building establishment at Woburn Abbey is on a princely scale, comprising extensive machinery, worked by a steam-engine of twenty-five horse power, and provides employment for 200 workmen.

In Devonshire the duke is carrying out the same spirit of improvement, to the extent of sixty-four cottages.

The example thus nobly set by the Duke of Bedford has been speedily followed by his grace the Duke of Northumberland, and other landed proprietors have also undertaken the same good work.

Plans of cottages built by the Marquis of Breadalbane, are published in the volumes for 1843 and 1845, of the *Transactions* of the Highland and Agricultural Society of Scotland; and plans of the Duke of Bedford's cottages are published in the last July number of the *Journal* of the Royal Agricultural Society.

To facilitate the adoption of plans which combine in their arrangement every point essential to the health, comfort, and moral habits of the labourer and his family, with that due regard to stability and economy of construction which is essential to their general usefulness, the Society for Improving the Condition of the Labouring Classes published, and circulated extensively, a series of designs for cottages, prepared with these special objects in view.

Each dwelling consists of a living-room, the general superficial dimension of which is about 150 feet clear of the chimney projection. A scullery containing not less than about 60 feet or 70 feet superficial, which is of sufficient size for ordinary domestic purposes, without offering the temptation to its use as a living-room for the family; besides a copper, and in some cases a brick oven, provision is made for a fire-place in all the sculleries, by which arrangement the necessity for a fire in the living-room through the summer is avoided. A pantry for food, a closet in the living-room, and a fuel store out of the scullery, are provided in all the cottages.

The sleeping apartments vary somewhat in dimensions; that for the parents in no instance contains less than about 100 feet superficial, whilst the smaller rooms for the children average from 70 feet to 80 feet superficial. The height from the ground floor to the first floor is 8 ft. 9 in. giving nearly 8 feet clear height for the living-room. The bed-rooms are 7 ft. 9 in. where ceiled to the collar pieces, and 4 feet to the top of the wall-plate, which, for the security of the roof, is in no case severed by the dormer windows.

In reference to situation, where it is practicable the front should have somewhat of a southern aspect; the embosoming in trees should be avoided, and particular attention ought to be paid to secure a dry foundation; where this is not otherwise obtainable, artificial means should be adopted by forming a substratum of concrete, about twelve inches thick, or by bedding slate in cement, or laying asphalte through the whole thickness of the wall under the floor level. The vicinity of good water and proper drainage are points of obvious importance. A gravelly soil is always preferable to clay, and a low situation is seldom healthy.

It is desirable that every cottage should stand in its own inclosed garden of not less than about $\frac{1}{8}$-th of an acre, and have a separate entrance from the public road. One well may generally be made to answer for two or more cottages, and it is of great importance that it be so placed as not to be liable to contamination either from the drains, cesspools, or liquid manure tank; the latter should, however, invariably be made water-tight, the cost of which will soon be repaid to the tenant by its fertilising products.

As respects the material used in the external walls of cottages, much must depend on local circumstances, and the facility with which the various kinds of natural or artificial substances adapted to the purpose are obtainable.

The various designs published by the Society have, for the reasons previously stated, been wholly arranged for brick, but by increasing the thickness of the external walls they will be equally well adapted for cottages built with other materials. The external walls are described as 9 inches thick, and when built of this substance, in order to secure their dryness, unless the bricks are unusually impervious to moisture, it is strongly recommended that the walls should be hollow; this may be effected by three methods, two of which require that the bricks be made on purpose. The plan No. 1 has been used to some extent; and unless where the bricks are so porous as to cause a transmission of moisture through the heading courses, this plan will be found to answer, rendering the walls dryer and cheaper than when built in the ordinary way. Three courses, with the joints, rise 1 foot, the bricks being $3\frac{3}{4}$ square; they are of the ordinary length—viz., 9 inches.

The other plan is that of hollow bricks made wedge-shaped, and bonded longitudinally over each other, so that two cavities run parallel through every course of bricks, giving a double security against moisture, as there are no holders to pass through the wall; the rise of these bricks is also three courses to the foot, and they are 12 inches long, which diminishes the number of joints, and gives greater boldness to the work, more resembling stone in effect. These bricks are patented; they may be easily made with any tile machine at a small cost per thousand above that of sound common stocks; whilst from their increased size, which adds but little to their weight, and nothing to the duty, it is found that nine of them will do the same number of cube feet of walling as sixteen ordinary stocks. The saving in mortar is full 25 per cent., and the labour, to accustomed workmen, considerably less than to ordinary brickwork; whilst great facility is afforded by the cavities both for ventilation and warming. It should be added that the bricks for the quoins and jambs may be either solid or perforated perpendicularly.*

* In addition to the patent bonded hollow-bricks, the application of which to the cot-

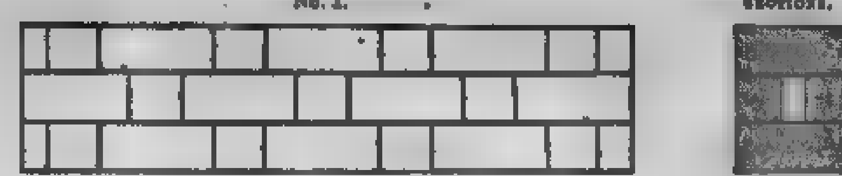
Where it is impracticable to obtain bricks made on either of the plans above described, the walls may be built hollow, 11 inches wide, with common bricks, (see Plan, No. 3); a cavity of 2 inches being left in the centre, and the length of the headers being made up with 2-inch closure, would bond every course and render them perfectly dry.

Where flint or concrete is used, the walls cannot be less than 12 inches thick with either material; they may be lined with the patent hollow brick, which would bond every course.

The main partitions on the ground-floor should be of brick—hollow bricks, or Messrs. Hertzlet and Co.'s rebated tiles, 12 inches square, where obtainable, may with advantage and economy be used for this purpose; in either case, they should be set in Roman or Portland cement. Where the upper-floor partitions stand perpendicular over those to the ground-floor, brick or tile is decidedly preferable to wood. Stairs may also be made of fire-brick clay, with great advantage. The ground-floor should be raised not less than six inches above the external surface, and where wood floors are used they ought to be ventilated by means of air-bricks built in the external walls. The warmest and most economical floor is probably that formed with hollow bricks. In some parts of the country, lime and sand floors are pretty generally used, and found to last, when well made, upwards of forty years.

Tiles will generally be found a preferable covering for the roofs to slate, being warmer in the winter and cooler in summer, and requiring much less lead, are decidedly more economical in some localities; however, slate may more effectually exclude the weather.

No. 1. SECTIONS.

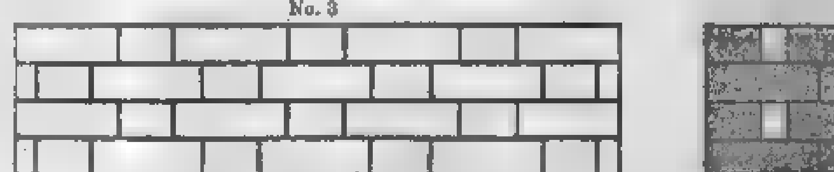


9in. HOLLOW BRICK WALLING AS AT WOBURN.

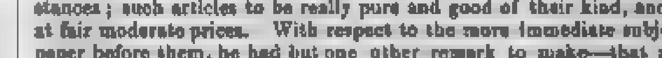
No. 2.

9in. PATENT BONDED HOLLOW BRICK WALLING.

No. 3



11in. COMMON HOLLOW BRICK WALLING.



In closing these remarks on the Dwellings of the Labouring Classes, I cannot but add that it will be to me a source of permanent satisfaction if they should prove of any service to the members of the Institute, or conduce in any way to the removal of obstacles which present so formidable a barrier to the social and religious advancement of a numerous and deserving class of the community.

To contribute to the welfare of our fellow-creatures, with a view to the glory of God, carries with it that durable happiness which the pursuit of wealth, of fame, or of fleeting pleasure cannot afford.

Mr. Sydney Smirke, V.P., rose to express his thanks to Mr. Roberts for laying before the meeting his views on this important subject, and also for the clear, intelligible, and accurate manner in which he had done so. This was a subject of great public interest and importance. It was a subject he had long felt an interest in, and he (Mr. Smirke) believed that his attention was first directed to it by becoming acquainted with the fact that an individual, enjoying the luxury of a private carriage, and giving his son the benefits of an university education, derived his income from some low lodging-houses in St. Giles's. This was sufficient to satisfy him of the inordinate extent to which the poor were surcharged for their habitations; of one thing he was quite certain, namely, that the poor paid far more, in proportion, than the rich, for their lodgings and food. This was now pretty well understood to be the case with regard to their lodgings. It must also be admitted to be the case with respect to their food: it was impossible, in all London, from Bond-street to Cheapside, to go into any more extravagant shop than the small chandlers' in the suburbs of London. In such places the worst possible article was sold at the highest possible price. The owners of those establishments had realised that summum bonum of political economy—they bought in the cheapest market, and sold in the dearest. He did not think we should have done all we could, or ought to do, for the improvement of the working classes, until we shall have used every possible exertion to secure for them those two great requirements, namely, cheap and healthy lodgings, and cheap and wholesome food. From what Mr. Roberts had detailed that evening, he (Mr. Smirke) thought that the poor were in a fair way to obtain the first-mentioned desideratum, and he hoped that with respect to the second, success need not be regarded as impossible. He (Mr. Smirke) hoped he might be permitted to suggest the establishment, in every parish, of a large store of the principal articles of food consumed by the poor, to be sold only to those who were known to be in needy circumstances; such articles to be really pure and good of their kind, and charged at fair moderate prices. With respect to the more immediate subject of the paper before them, he had but one other remark to make—that all those, who had from circumstances been enabled to know anything of the habits of the working classes in their own homes, must admit, that as tenants, they were rather a destructive class. On this account he thought the interior fittings of all dwellings for the poor should be formed as indestructible as possible: plaster was not fit for the walls of the rooms; the chimney hearths should be of cast-iron, and the ironmongery generally should be of special strength and simplicity.

Captain Bullen, R.N., observed, that some years ago he made tiles a foot long and six inches thick, and as he used them singly the walls were only six inches thick. He plastered them inside, and they are very dry, except when there is much wind and driving rain. He sometimes used those bricks for flooring, as they are very dry. An objection, however, arose to their use. It was a very dry place where he introduced them, and the ants finding them comfortable residences, crept in, and often annoyed people by eating up their bread and butter. In other respects they answered the purposes anticipated. Two cottages built together cost him about 100*l.*, consisting of two rooms and a kitchen, 13 feet square, all on the ground floor.

Mr. Godwin called attention to the oppressive and injurious tendency of the window-tax on such dwellings, and hoped that all present would aid in leading ministers to consider a matter of such moment.

The Rev. Mr. Endrup stated, that having had some experience in visiting the poor, both in town and country, he could assure the meeting that the condition of their dwellings was one of the greatest obstacles the clergy had to contend against, in endeavouring to make their moral condition better and holier. The miserable state in which many of them are compelled to live, constitutes the chief difficulty. The bed-rooms of the poor are often so over-crowded that modesty, reverence, and decorum are almost entirely destroyed. He strongly sympathised therefore in this admirable movement for the benefit of the labouring classes.

struction of walls has been fully described it may be useful to give a section and description of a hollow brick, designed by Mr. Rawlinson, C.E., whose attention has been much directed to this subject, and who states that it combines many advantages, and may be moulded as easily as any other form. The angle ribs in the inside give strength and surface at that portion of the joint, and admit of tile or slate dowels being inserted on any or all of the sides, to close the joint; by this means a continuous flue, perfectly tight, may be formed. Two of the external faces are even and plain, two are partially recessed; these latter are supposed to be the beds or side-joints, as the case may be, the slight sinking of about 1-16th of an inch being to relieve the hollow side and thin portion of the brick from undue weight or bearing in the work,—to bring this on the solid edges, and also to act as a slight lock, or dowel, with the cement or mortar. The joint-dowels will only be required where one surface or more is exposed, or where any particular course requires to be made into a continuous flue, for ventilation or any other purpose. For partitions, or for lining external walls, where plaster is to be used, the dowel will not be required.

MEDIÆVAL BRICK BUILDINGS OF GERMANY.

On the Mediæval Brick Buildings in the North-East of Germany, and on the Coast of the Baltic. By Charles Fowler, Jun., Esq.—(Paper read at the Royal Institute of British Architects, February 18th.)

In requesting your attention to some of the examples of the Mediæval Brick Buildings which we find in the north-east of Germany, and the adjoining coasts of the Baltic, I can hardly preface my remarks better than by laying before you the observations of one of the best authorities on the history of our art—I mean Dr. Franz Kugler, who, in reference to the buildings in question, says in his Handbook: "The *Germanic style* is developed in a peculiar manner on the coasts of the Baltic, and in some of the adjoining districts of Germany, viz., Holstein, Mecklenburg, Pomerania, the Old and New Mark Brandenburg, Prussia, Curland, Liefland, and also in the Scandinavian countries. These countries were connected and very much influenced by the confederation of the Hanse towns, and it is probably to this influence that we may ascribe much of the similarity of style visible in the buildings of the districts referred to, though, in some instances, other circumstances may have concurred to produce many of the peculiarities which we find. The Germanic style of the Baltic countries is distinguished from that development of it which attained the greatest perfection in *Western Germany*, by its greater simplicity and massiveness; though it is by no means devoid of artistic feeling, particularly in the bold proportions of the interiors, and externally in a peculiar style of ornament. It has been thought by some that the peculiarities of this style are to be accounted for entirely by the materials principally used in the construction: granite and brick, the former difficult to handle, the latter only obtainable in blocks of very small dimensions; but without wishing altogether to deny this influence of material, we shall more probably find the origin of this simple and peculiar, but effective style of architecture, in the rude but energetic character of the people by whom the monuments in question were erected. The influence of material is more decidedly visible in the decorative parts.

This peculiar style appears to extend over a considerable tract of country, but its most complete development is found in the Old Mark Brandenburg, and the principal Hanse towns, Hamburg and Lubeck. The earliest buildings in which brick appears as the prevailing material date their commencement in the latter part of the 12th century. But it is not till the end of the 13th century that we find any examples of importance, and the style was fully developed during the 14th and down to the middle of the 15th centuries. The earliest examples of this style are, as might be expected, ecclesiastical structures, and the prevailing character of these is, as we have already heard, simplicity and massiveness. The form of the plan is at first the cross, the choir having a polygonal apse with the aisle continued round it, and sometimes also small chapels spreading beyond; the floor of the choir is considerably raised, and a crypt formed under it; but the transepts were sometimes omitted, retaining the same arrangement of the choir. The best examples of this early style are to be found in the churches of Rive, Odensee, Ringstädt, Roskilde-on-Zeeland, and the adjoining islands.

In these examples we find the semi-arch, small windows, and many other features of the Romanesque buildings, with which they are nearly coeval, but probably a little later. But by far the greater number of existing examples belong to a later period, as already mentioned, and these exhibit more peculiar features. The plan now presents nave and aisles only, the choir still terminates polygonally, and the aisle is sometimes continued round it; but frequently the aisles are also closed at the east end by a small apsis, and in this case the choir is continued eastward beyond the aisles; the choir is always marked by being raised a few steps. The space between the wide projecting buttresses is sometimes occupied by small chapels, both round the east end and at the sides of the aisles. The towers are, I think, invariably placed at the west end only; and there is most commonly only one, which is imbedded in the body of the church, so that the west façade is unbroken, and the tower only shows itself above the roof; in this arrangement buttresses would not have added to the apparent stability. The aisles are of equal height with the nave, or at least the vaulting springs from the same line. The roof is generally in one span over nave and aisles, rendering it a very important feature externally from its necessarily great height; the usual covering is copper. The windows are of narrow proportions, and without transoms; the tracery, where not of stone, is of a very simple and even rude character, though there are exceptions. The doorways are generally small, but deeply recessed, with rich mouldings; porches are not common, but I am able to exhibit one example from the Dom Lübeck. The form of the arches is generally about the equilateral, the pier arches more depressed. The piers are mostly of simple form, as circular or octagon, with four attached vaulting shafts; but there are examples of a more elaborate composition. The vaulting is generally the simplest form of cross vault, without any wall or ridge ribs; in each compartment, between the transverse ribs, the vault rises domically, so that there can hardly be said to be any ridge at all, as the vertical section through the centre of the vaulting would present somewhat the appearance of a series of irregular shaped domes; and, probably with a view to lighten the construction, the centre is left as an open eye, round which the moulding of the ribs is continued. In some instances the brick-work of the interior has been simply pointed, and left without any plastering or colouring except in the vaulting; this treatment, though it produces rather a gloomy effect, is perhaps preferable to the indiscriminate whitewash.

Of the exterior the most striking feature are the towers, though usually single, and placed at the centre of the west front. They are of large dimensions, both on plan and in elevation, but of exceedingly simple outline; without buttresses, and with scarcely any ornament but the bands of sunk tracery which divide the different stories. The openings are small, too much so apparently to let out the sound of the bells; some of the smaller of these are therefore occasionally found on the outside, in a kind of balcony. The towers are most commonly square, up to the commencement of the spire, which is octagonal, and constructed of wood covered with copper or lead; the transition is made by gables on the four sides of the tower, but there are some examples where the upper part of the tower itself is octagonal.

The Spire is generally more than half the whole height, without any attempt at ornament, and terminates in a simple vane. The form is very taper, and is elegant from its simplicity; essentially different from the heavy spires of the Romanesque churches on the Rhine, which in construction they resemble.

As the Roof is generally continuous over both the nave and the choir, the division is marked externally by a kind of lantern with a small spire, placed on the ridge of the roof; and this is called a Roofrider, a term very expressive of its position, though the saddle is none of the easiest.

Most of the towns of the Mark offer several examples; I shall therefore only take some of the most important with which I am acquainted. The Church of St. Mary's, Lübeck (1250—1360) is one of the most striking; its great size, the two lofty towers, and the circumstance of its having the exceptional arrangement of a clerestory, all contribute to render it so. The extreme length inside is 340 feet, and the height of the nave 126 feet. The Briefkapelle, which is a rather later addition on the south side, is one of the most elaborate and interesting specimens of this style with which I am acquainted. The vaulting is supported by two octagon polished granite shafts, 14 inches diameter and 36 feet high. I will here just mention the heights of the different church towers at Lübeck, which are certainly very much beyond our usual standard.

Height of Tower of	St. Peter's	364	English feet.
" "	St. Ægidius	312	"
" "	St. James's	316	"
" "	The Dom	391	"
" "	St. Mary's	404	"

The Dom (1174—1341) is the oldest church in the town; it has likewise two towers. Of the early part we have not much left, it is at the west end: the north porch, judging from the mouldings, cannot, however, be much later than 1200. The Church of St. Katharine (about 1320) has a remarkable arrangement of the choir, which forms a kind of gallery, raised on columns and vaulting, and was so disposed for the convenience of the nuns of the convent to which this church was attached. There is one other of the ecclesiastical buildings of this city which deserves particular notice; the so-called *Heiligen Geist Spital* (Hospital of the Holy Ghost), founded 1234, now a church, but originally a religious establishment for the reception of the sick and wounded that returned from the Holy Land, and for sick travellers generally. The west front is very peculiar; this part of the building formed originally the chapel of the Hospital, it is now only the vestibule to the church. At Hamburgh the churches have suffered more from modern alteration and destruction: the great fire in 1842 destroyed two of them, St. Peter's and St. Nicolas. Only two of the original churches now remain, and they have been much altered.

The small town of Tangermünde, on the Elbe, contains some very good examples—the Conventual Church and St. Stephen's; in the latter much of the moulded work is in stone. A short distance from this town there is a very interesting example of the early period of the brick style, in the church at Jerichow (before 1200), in which the semicircular arch is used throughout; there is also a crypt; the cloisters, which still remain, show this to have been a conventual church. Not far from Tangermünde, in another direction, is situated the ancient capital of the Mark Brandenburg—Stenthal, where there are several fine churches of the brick style (the Dom, St. Mary's, St. James's, and St. Peter's), all on a very large scale. At Brandenburg, the Dom affords another example of the earlier period, at least in part. The Church of St. Katharine (1401), partakes externally rather of the civil than ecclesiastical character; the façade has a stepped gable. I will only mention further the Church of St. Nicolas, at Stralsund (begun 1311), and that of St. Mary, at Stargard, in Pomerania, both of which are stated to be particularly fine examples of the style.

We will now turn to the *Civil Architecture* of the brick style, examples of which do not occur till about the latter part of the fourteenth century, and they are generally of a much more elaborate character, with greater subdivision of parts, and more profuse decoration. Among these buildings the town halls or senate houses form an important class, but they will hardly admit of any general description; further, the gate towers and other fortifications are very worthy of notice; and lastly the private houses, though these do not offer any very great variety. We will therefore proceed at once to examine some of the examples.

The senate house at Lübeck is perhaps the most important of its class, as that town was at the head of the Hanse Confederation, and the delegates from the different cities met in the senate house there, which is therefore much larger than would have been necessary for the purposes of the town council alone. The erection of this building spreads over a considerable period, down as late as the beginning of the sixteenth century, but the most interesting portion is that first erected. It consists of an open arcade, on granite piers, on the ground floor, probably for the use of the market, over which were the halls, &c., lighted by large windows. The roof is masked by a row of turrets, connected by a kind of arcade, which gives a peculiar character to the building.

The town hall at Tangermünde is an example of a different class; the most remarkable feature is the gable end, richly decorated with octagon buttresses, having stories of canopied niches,—the gable is stepped between these buttresses. Altogether it strongly resembles the façade of the Church of St. Katharine, at Brandenburg, and dates probably from the same period, the beginning of the fifteenth century.

The Hall of Justice (as it is called) at Brandenburg presents a somewhat different arrangement; it is by no means so fine an example as that last mentioned. The arrangement of the centre of the front is very peculiar; there is elaborate tracery at the heads of the door and windows, and this, if coeval with the rest of the building, would assign a late date for its erection.

Having before alluded to Stralsund, I will here mention that the town hall there (built 1316) is spoken of as having seven towers, most probably somewhat in the manner of that at Lübeck. There are numerous other examples, which appear mostly to date from the fourteenth and beginning of the fifteenth centuries.

Many towns of the district we are considering appear to have been fortified by a continuous wall, generally of brick-work with turrets at intervals, and with large gate-towers, both single and double. Very fine examples of the latter are found at Lübeck, but the enceinte appears in this case to have been an earth-work, though not that now existing. These towers were, without doubt, originally crowned with battlements, as is still the case in some other examples; but even as they now are they form imposing entrances to the town. The date of these buildings would appear to fall in the middle of the fifteenth century. At Tangermünde the wall is of brick, and remains almost perfect, and there are also some fine gate-towers. At Stenthal we find two good examples of this class of building, at Brandenburg several, and many others.

But I must pass on to another class of examples—the private buildings, of which I find the following description in an old chronicle of the town of Lübeck:—"On one or both sides of the lofty door there is a sitting-room, and at the back a small bed-room, over the former the business room; it was some time before any other window was introduced, besides that common to the sitting and business rooms; the hall for the goods and the several stories in the roof had only wooden shutters." This description is of the houses of the fourteenth century, but with very slight alterations it would embrace the greater part of the town at this day.

In 1509 the town of Lübeck was nearly destroyed by fire, and previous to this period the private buildings were probably entirely constructed of wood, as after the fire the senate passed a *Building Act*, which ordered that at least both the gable ends of private houses should be of brick. The principal feature of the private buildings are the stepped gables, which are sometimes of great height, and of which every possible variety is met with. They are decorated with long strips of panels, arch-headed, and divided into stories of niches and openings; these panels are never continued down over the lower part of the house, where the openings have frequently quite a different arrangement. The steps of the gables are very bold, giving a peculiar picturesque character not met with in similar buildings elsewhere. Most of the openings of windows and doors have the segmental arch, being more manageable than the pointed form which is given to those of the niches or panels.

The treatment of the *ornamental* parts in this style is peculiar and well adapted to the material in which they are executed. There is one feature in particular which deserves attention, I mean the introduction of a white plastered ground to relieve the forms of tracery, &c. put over it. This relief by *colour* is rendered necessary by the *dark* hue of the material, owing to which the *shadow* of small projections would not give sufficient relief.

In the early examples of the brick style, the more elaborate parts, including the tracery of the windows and other moulded work, were executed in stone. Horizontal bands of stone were also occasionally introduced, and they have a good effect in tying together the different parts of the composition, besides their value in a constructive point of view. But in the later examples from the end of the fourteenth century, stone is entirely dispensed with, and we find even such parts as crockets and finials executed in *brick*. The use of dark brown or black glazed bricks was also common during the later period. The character of the mouldings varies, of course, somewhat in the different periods, being simpler in the earlier, and more elaborately subdivided in the later; delicacy of profile can hardly be expected from the nature of the material. Moulded bricks were also used to make up general forms, such as circular piers, the inner side of circular turrets, &c.

There are a *few* points in the construction of the buildings we have been examining which ought not to be passed over. There is usually a granite plinth carried all round the churches, and the towers are faced with the same several feet up. The absence of buttresses to the towers rendered it necessary to increase the thickness of the walls, which we find is very considerable, notwithstanding which they mostly incline from the upright; and it is remarkable that this occurs most frequently towards the south-west. While speaking of the mortar joints, I should mention that they are invariably very wide (from $\frac{1}{2}$-inch to $\frac{3}{4}$-inch or even more); the mortar itself is extremely hard, and the lime used was, for the district we are considering, principally supplied from Segeberg in Holstein.

The construction of *vaulting*, I think, claims particular attention; in the first place, a light material was prepared in bricks, moulded of a wedge form. The ribs seem to have been first constructed, independently, as a skeleton, and between them the spandrils were filled in with the light bricks, apparently without the use of centring, as each spandril is considerably arched up to enable it to support its own or any superincumbent weight; thus the vaulting rests entirely on the ribs, which are not tailed into it. It is a single brick in thickness, about six inches, and is backed up only a very short distance above the springing, so that the form is very distinctly seen on the upper surface, where it presents a very remarkable appearance. The bond used throughout is the Flemish, or, as it is there called, the cross-bond; the arches are always built in half-brick rings.

The bricks used in the buildings I have brought under your notice are of a larger size than those now commonly used in the district; they are remarkably hard and sound, and are rather heavy; though externally of a brown red colour, the inside is grey, like our stocks: this is not the case with those now made. The light vaulting bricks were made with a mixture of chopped straw, so that when burnt they were porous, but of sufficient strength for their purpose. I have discovered no examples of gauged work. The first-class bricks, as a material, are superior to those used in this country: the colour uniformly red, except where a vitreous action had been produced in the burning. There did not appear to have been a rubbing down of the face of the material when used for mullions or tracery—the ordinary examples presented too rude a surface to suppose such an operation.

Remarks made at the Meeting after the reading of the foregoing Paper.

Mr. SMIRKE said that he had recently been much interested by a cursory inspection of some examples of old brick-work in Germany. At Hanover and Hamburgh there are churches constructed of brick, with windows having deeply-moulded jambs, and slender mullions of considerable height, wholly of that material. He thought that these instances might be adduced in corroboration of a remark he had made here on a former occasion, that we are in England scarcely aware of the great capabilities of terra-cotta. The application of burnt clay to the purposes of ornamental architecture seems to have been carried farthest in flat alluvial countries, as on the eastern side of England and in western Germany, where, of course, good building stone does not occur, and where the expense and difficulty of transit in former times encouraged the use of artificial materials. In Norfolk and Suffolk, and the adjacent counties, many examples remain of delicate ornamental brick-work. In parts of Germany this fabric is at the present day far better understood than with us. The Bauschule at Berlin is a most remarkable specimen of Schinkel's genius: it is a building of very great extent, and of most elaborate detail, entirely executed in brick-work, unrelieved by any portion of stone. Its dark red colour gives to the building a somewhat heavy general effect, very similar to the red sandstone so much used in some parts of England, but on a close inspection one is surprised at the fineness and delicacy of the details. Throughout western Germany bricks are worked with a fantastic ingenuity rarely visible with us; by the use of various coloured bricks intermixed, an ornamental character is given to the commonest buildings—somewhat whimsical perhaps to our plain English eyes, but yet well deserving observation.

Mr. FOWLER, sen., had been struck when abroad with the curious specimens of brick-work which he met with, particularly the Old Rathhaus, Hanover. Schinkel's remarkable building at Berlin, whatever might be its merits architecturally, was a striking example of what might be done in brick-work or terra-cotta. The whole of that immense structure was of that material, and it was certainly executed in a very extraordinary manner. It was by no means striking in its outline. He would not have ventured to say that in Berlin, where the worth of Schinkel's works must not be doubted, but he would assert here, that as a piece of architecture it possessed no great merit. It did far greater credit to the person who executed the work; for the able manner in which the details were carried out was surprising, and served to show, beyond what he would have conceived possible, the capability of brick-work as a material. These examples, in stricter phrase, related to terra-cotta rather than to vulgar brick.

Mr. BELLAMY (the Chairman), remarked that Mr. Sharpe, of Lancaster, had introduced terra-cotta to a great extent in the construction of churches, and with considerable effect. There was, however, at the present time, rather an affectation in the application of brick-work, which it was not desirable to encourage. He had seen instances in which the cost of ornamental construction in brick had exceeded that of stone; whilst, notwithstanding the beautiful effect sometimes produced by a judicious combination of the two materials, it must be admitted to fall short of that obtainable in stone. The practical objection to the combination of rubbed and gauged bricks with the ordinary building brick, by which bond is interrupted and not recovered for several courses, should not be lost sight of in adopting that material.

Mr. DONALDSON considered that the absence of buttresses, alluded to by the lecturer, on the external faces of these brick edifices materially detracted from their effect. The massive buildings rising up with the landscape, possessed great boldness in point of mass, but at the same time they exhibited great want of taste. High as their spires rose, and imposing as were their dimensions, they were remarkable for a want of *chiaroscuro* and contrast, which marred their appearance as works of art. The influence of Flemish taste in our brick-work was perceptible in many examples of past times, which might be accounted for by the fact, that the Flemish builders were brought over to execute brick constructions similar to their own. But in this country brick-work, as applied to Gothic detail, had never been carried to the same extent as in the low countries. Our travellers abroad had not so much noticed, as they deserved, the edifices to which attention had been drawn by Mr. Fowler, for the surface of many had been coloured over with a light tint, and they appeared to persons passing through those towns as though they were really of stone, instead of being simply of brick construction.

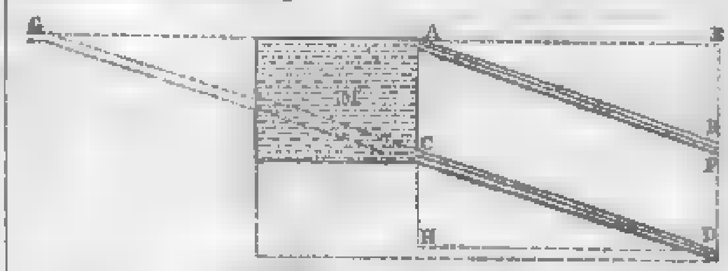
A vote of thanks was then passed unanimously to Mr. Fowler, for his interesting communication.

Ploughing by Steam.—A trial in this way was made at Grimsthorpe, on the 7th ult, by Lord Willoughby de Eresby. It will be sufficient at present to say that the machinery employed consisted of a small locomotive engine, with a capstan attached, moving on a portable railway. An ordinary plough, followed closely by a subsoil plough, was drawn by a chain from the capstan, working with perfect precision, and at a greater depth and speed than usual. Several gentlemen and farmers who were present, expressed a favourable opinion of the experiment. Should the plan be found advantageous, it will be published in full for the benefit of the public.

MOTION OF WATER IN PIPES.

On the Motion of Water in Conduit Pipes; on Friction and Pressure in Pipes; and on Jets d'Eau. By M. D'AUBUISSON DE VOISINS, Ingénieur en chef Directeur au Corps Royal des Mines, &c. &c. —(Translated by T. HOWARD, for the *Civil Engineer and Architect's Journal.*)

[THE Work, of which the present translation forms a part, must be considered as the most important and complete modern treatise on Hydraulic Engineering. In it the author has, with admirable clearness and precision, treated the entire question of the Motion of Fluids; and this in such a way as to render it equally inviting to the practical and the scientific man. The object of the translator is to supply a want which English engineers must long have felt—that of an intelligible explanation of the *Motion of Water in Pipes;* and in carrying out this object, he has considered it due to M. d'Aubuisson and the public, to give the exact meaning of the author as literally as possible. On the same principle, the original equations are given, as well as the same reduced for English feet; for though these reductions have been carefully made, more confidence will be felt in important calculations, where both can be referred to.—Unless otherwise expressed, the whole of the dimensions in the examples are understood to be in English feet, and the time in seconds.]



Similarity of the Motion in Pipes and in Canals.

1. In a long, inclined pipe, as in a canal, water moves by virtue of its gravity or weight, or rather that part of its weight called into action by the slope of the pipe: the accelerating force in both cases is gp.* So that, if to the upper part of a reservoir M, we adapt at AB, either a canal or a long pipe,—granting that no obstacle is opposed to the action of this force, the fluid will issue at the point B, with a velocity due to the height EB.

At the commencement of an open canal there is no exercise of pressure on the entering fluid; while there usually is a pressure at the head of pipes. For example, if we bring the pipe AB down to CD, we shall have at C a force of pressure, in consequence of which the water will enter into the pipe with a velocity due to the height AC. According to the first principles of accelerated motion, this velocity should be added to that which the fluid acquires from the effect of the slope from C to D; so that, every obstacle being removed, it will issue with a velocity due to AC + FD, or to ED, the height which represents the force, in virtue of which the flow tends to take place.

In every other respect, this case may again be compared to that of a canal: if we prolong CD up to G, level with the surface of the reservoir, and make a canal from G to D, the water will still tend to run out with a velocity due to ED. Thus, in both cases, in pipes as well as in canals, the accelerating force and the effects which it tends to produce, are the same.

Under the influence of such a force, the motion in pipes should be continually accelerated; and yet, at a very short distance from their origin, it is perceptibly uniform. There must then be, beyond that distance, an opposing force which continually destroys the effect of the former. This opposing force can only be the resistance of the sides of the pipe; a resistance which, as in a canal, arises from the adherence of the fluid particles to these sides and amongst each other.

Thus in pipes we have the same accelerating and retarding forces as in canals; the motion therein is of the same nature: and we may say that pipes differ but in one point from canals—that of having the upper part of the channel closed.

Meanwhile, this difference in the form of the channel gives rise to peculiar circumstances in the movement, which demand special consideration: they will form the subject of this chapter.

* g being velocity acquired from force of gravity in 1 second = 32·19 feet, lat. of London. p being rate of slope, or fall ÷ length.

Art. I.—OF SIMPLE CONDUITS.

In hydraulics, and particularly in connection with water-works, the name of *conduit* is given to a long series of pipes, joined, exactly one to another. The conduit is called *simple* (in opposition to *a system of conduits*) when it consists of only a single line of pipes, conducting to its extreme end all the water it receives at its origin.

1. Straight Conduits of Uniform Diameter.

Manner of expressing the Resistance.

2. For greater simplicity, let us unite in one the two forces which tend to produce the velocity of flow—the pressure AC at the head of the conduit, and that of FD which arises from the slope: for this purpose, let us imagine that the given conduit CD is placed horizontally at HI, at the bottom of a reservoir, of which the depth AH = AC + FD = ED. Nothing will be changed in the data of the problem: we shall have the same force and the same resistance, the latter being independent of the position of the conduit.

The force of pressure by reason of which the water tends to run out, or more immediately, the vertical height ED, which is the difference of level between the orifice of discharge and the surface of the fluid in the reservoir, is called the head (*charge de la conduite*). We shall designate it by H.

If the conduit offered no resistance to the motion, setting aside the effect of contraction at the entry, the water would run out with a velocity due to this total height, as we have just seen. But it is not so: the resistance of the sides opposing an obstacle, diminishes this velocity; it consequently absorbs a portion of the motive head H. The flow takes place only by virtue of the remaining portion; which portion is simply the height due to the velocity of discharge, or indeed to the velocity at any point of the conduit, since the motion therein is uniform, and the section everywhere the same.

Let v be this velocity, $\frac{v^2}{2g}$ will be the height due to the velocity or the effective portion of the head; $H - \frac{v^2}{2g}$ will then be the portion absorbed by the resistance.

3. We have thus expressed, by the height H, the effort or the force of pressure which drives the water in the conduit; by the height $\frac{v^2}{2g}$, the force which produces the discharge; and by another lineal quantity $H - \frac{v^2}{2g}$, the resistance or negative force: although it is a principle in mechanics that forces of pressure, or efforts equivalent to weights, ought also to be expressed by weights. I will explain myself on this subject.

We have, in a former chapter, seen that the absolute pressure on a fluid horizontal plane, or portion of that plane, designated by s, was psH lbs., p being the specific gravity of the pressing liquid. Since, according to the laws of hydrostatics, the pressure is equal on every part of this plane, it will be sufficient, and at the same time convenient, to consider but one part only; this will be an infinitely small one, which we may suppose always of the same area; then s being constant, the pressure will vary only with the specific gravity or the nature of the liquid, and the *height* of its column: it is in this sense that we say that the height of the column of mercury in the barometer expresses the pressure of the atmosphere. If the pressing liquid remain the same (as will be always the case with water in this chapter), we may also pass over its weight p, which is constant; and the pressure will be expressed simply by H, and will be exclusively proportional to it.

If we were rigorously to adhere to the principle, we should regard H as the weight of the fluid filament which presses and drives on in the conduit the molecule which is immediately beneath it; and we should represent it by a line, as in elementary statics we represent by lines, forces which are also weights.

Amount of the Resistance—Fundamental Equation.

4. Since the resistance arises from the effect of the sides, it will be proportional to their superficies—that is to say, to the length of the conduit, and to the circumference of its section, which is here the wet perimeter; for we are supposing that the flow is made in a full pipe, otherwise we should have the case of a simple canal. In other words, the more the section is enlarged, the more also will the resistance of the sides be distributed among a greater number of molecules; consequently, it will less affect each of them and the total mass; it will be in inverse ratio to their number, and consequently to the magnitude of the section. In short, here, as in canals, it will be proportional to the square of the velocity plus a fraction of the simple velocity.

Then, if L be the length of the conduit, S its section, C the wet contour or perimeter, a and b two constant coefficients, the expression of the resistance will be

$$a\frac{CL}{S}(v^2 + bv).$$

and we shall have

$$H - \frac{v^2}{2g} = a\frac{CL}{S}(v^2 + bv) \quad \ldots\ldots\ldots\ldots\ldots\ldots (I.)$$

5. It remains to determine the coefficients a and b. M. Prony, who was the first to undertake this task in an adequate manner, makes use, for the purpose, of fifty-one experiments made by our most able hydraulicians, and which Du Buat had before employed in the establishment of his formulæ. He has deduced therefrom,

$$a = \cdot 0003485; \qquad b = \cdot 0498;$$

or, in the value of English feet, $a = \cdot 0001062$; $b = \cdot 16339$.

Of these fifty-one experiments, eighteen had been made by Du Buat himself, upon a tin pipe, of 1·063 inches diameter and 65·6 feet long; twenty-six had been made by Bossut, on tubes also of tin, 1·06 inches, 1·42 inches, and 2·13 inches diameter, and whose lengths varied from 31·95 feet to 192 feet; lastly, seven had been made on the large conduits in the park at Versailles, one was 5·3 inches diameter and 7479 feet long, and another 19·3 inches diameter and 3834 feet long.

Twelve years afterwards, Eytelwein treated anew the question of the motion of running waters; he has thought it right to take into consideration the contraction of the vein at the entrance of the conduit, and m being the coefficient for this contraction, he determined (the measures being in mètres),

$$\left.\begin{array}{l} H - \dfrac{v^2}{2g \times m^2} = \cdot 0002808\,\dfrac{CL}{S}(v^2 + \cdot 084\,v) \\ \text{Or in English feet,} \\ H - \dfrac{v^2}{2g \times m^2} = \cdot 0000854\,\dfrac{CL}{S}(v^2 + \cdot 2756\,v) \end{array}\right\} \ldots\ldots (II.)$$

But m, whose effect, besides being imperceptible in large conduits, is included in the value of a, given by the experiments. Consequently, and paying regard only to the most exact observations, and especially to those of Couplet, I shall adopt the equation,

$$\left.\begin{array}{ll} \text{[In mètres]} & H - \dfrac{v^2}{2g} = \cdot 0003425\,\dfrac{CL}{S}(v^2 + \cdot 055\,v) \\ \text{[In Eng. feet]} & H - \dfrac{v^2}{2g} = \cdot 0001044\,\dfrac{CL}{S}(v^2 + \cdot 18045\,v) \end{array}\right\} \ldots (III.)$$

For *canals*, the equation is,

$$\left.\begin{array}{ll} \text{[In mètres]} & H - \dfrac{v^2}{2g} = \cdot 0003655\,\dfrac{CL}{S}(v^2 + \cdot 066\,v) \\ \text{[In Eng. feet]} & H - \dfrac{v^2}{2g} = \cdot 0001114\,\dfrac{CL}{S}(v^2 + \cdot 21654\,v) \end{array}\right\} \ldots\ldots (IV.)$$

These two equations are similar and very nearly the same, as should be the case. The slight differences in the numerical coefficients probably arise from errors in the observations. If this be so, as the observations are capable of being made with much greater exactness upon conduits than upon canals or rivers, it may be presumed that the coefficients of the equations for conduits are the more correct.

6. The section of pipes being a circle, if D represent the diameter, we shall have $S = \pi' D^2$, and $C = \pi D$; and by putting for π, π', and g, their numerical values,* the fundamental equation for the motion of water in conduit pipes will become,

$$\left.\begin{array}{ll} \text{[In mètres]} & H - \cdot 051\,v^2 = \cdot 00137\,\dfrac{L}{D}(v^2 + \cdot 055\,v) \\ \text{[In feet]} & H - \cdot 0155\,v^2 = \cdot 0004176\,\dfrac{L}{D}(v^2 + \cdot 18045\,v) \end{array}\right\} \ldots\ldots (V.)$$

The velocity is very rarely among the quantities given or required in the problems to be resolved; the discharge is the

* $\pi = 3 \cdot 1416$, $\pi' = \cdot 7854$.
$\frac{1}{2g} = \cdot 051$ (in mètres). $\frac{1}{2g} = \cdot 0155$ (in English feet).

quantity more frequently sought. Let Q be the volume discharged in a second: we have

$$Q = \pi' D^2 v; \qquad \text{or } v = 1{\cdot}273\,\frac{Q}{D^2} \;\ldots\ldots\ldots\ldots\ldots\; \text{(VI.)}$$

This value of v, put in the equation above, transforms it to

$$\left.\begin{array}{ll} \text{[In mètr.]} & H - \cdot 06264\,\dfrac{Q^2}{D^4} = \cdot 002221\,\dfrac{L}{D^5}(Q^2 + \cdot 0432\,QD^2) \\ \text{[In feet]} & H - \cdot 02519\,\dfrac{Q^2}{D^4} = \cdot 000677\,\dfrac{L}{D^5}(Q^2 + \cdot 14173\,QD^2) \end{array}\right\}\ldots \text{(VII.)}$$

Such is the formula which we shall have to employ for the solution of questions relative to the motion of water in conduit pipes; attending always, in its practical application, to the observations which will hereafter follow. Of the four quantities Q, D, H, and L, three being given, the fourth may be found by this formula.

7. When the velocity is great, so as to exceed 2 feet per second, the resistance is sensibly proportional to the square of the velocity; the term in which it is but the first power disappears, and we have, according to the experiments of Couplet,

$$\left.\begin{array}{ll} \text{[In mètres]} & H - \cdot 051\,v^2 = \cdot 001436\,\dfrac{Lv^2}{D} \\ \text{[In feet]} & H - \cdot 0155\,v^2 = \cdot 0004373\,\dfrac{Lv^2}{D} \end{array}\right\}\ldots \text{(VIII.)}$$

Or, in terms of Q,

$$\left.\begin{array}{ll} \text{[In mètres]} & H - \cdot 08264\,\dfrac{Q^2}{D^4} = \cdot 002326\,\dfrac{LQ^2}{D^5} \\ \text{[In feet]} & H - \cdot 02519\,\dfrac{Q^2}{D^4} = \cdot 000709\,\dfrac{LQ^2}{D^5} \end{array}\right\}\ldots \text{(IX.)}$$

It will be borne in mind that the second member of the above equations is the value of the resistance arising from the sides of the conduit.

8. Disengaging the value of Q from the general equation, it becomes

$$\left.\begin{array}{ll} \text{[In mètr.]} & Q = -\dfrac{\cdot 0216\,LD^2}{L + 37{\cdot}2\,D} + \sqrt{\dfrac{450{\cdot}2\,HD^5}{L + 37{\cdot}2\,D} + \left(\dfrac{\cdot 0216\,LD^2}{L + 37{\cdot}2\,D}\right)^2} \\ \text{[In feet]} & Q = -\dfrac{\cdot 0709\,LD^2}{L + 37{\cdot}2\,D} + \sqrt{\dfrac{1477{\cdot}06\,HD^5}{L + 37{\cdot}2\,D} + \left(\dfrac{\cdot 2325\,LD^2}{L + 37{\cdot}2\,D}\right)^2} \end{array}\right\}\text{(X.)}$$

In long conduits, where 37 D is very little compared with L, we may neglect it; and again neglecting the second term under the root, we shall have for ordinary cases of practice,

$$\left.\begin{array}{ll} \text{[In mètres]} & Q = 21{\cdot}22\,\sqrt{\dfrac{HD^5}{L}} - \cdot 0216\,D^2 \\ \text{[In feet]} & Q = 38{\cdot}4365\,\sqrt{\dfrac{HD^5}{L}} - \cdot 0709\,D^2 \end{array}\right\}\ldots \text{(XI.)}$$

9. In great velocities, it is

$$\left.\begin{array}{ll} \text{[In mèt.]} & Q = 20{\cdot}73\,\sqrt{\dfrac{HD^5}{L + 35{\cdot}5\,D}};\ \text{or, } Q = 20{\cdot}3\,\sqrt{\dfrac{HD^5}{L}} \\ \text{[In feet]} & Q = 37{\cdot}034\,\sqrt{\dfrac{HD^5}{L + 35{\cdot}5\,D}};\ \text{or, } Q = 36{\cdot}77\,\sqrt{\dfrac{HD^5}{L}} \end{array}\right\}\text{.(XII.)}$$

If the velocity is required, we obtain its value by dividing the quantity Q by the section $\pi' D^2$.

Expression for the Diameter.

10. The diameter of conduits is very often the quantity we have to determine. The best method of obtaining it is by putting the fundamental equation under the following form:

$$\left.\begin{array}{ll} \text{[In mètres]} & D^5 - \left\{\cdot 00000694\,\dfrac{LQ}{H}\,D^2 + \cdot 0826\,\dfrac{Q^2}{H}\,D + \cdot 00222\,\dfrac{LQ^2}{H}\right\} = 0 \\ \text{[In feet]} & D^5 - \left\{\cdot 00009594\,\dfrac{LQ}{H}\,D^2 + \cdot 02519\,\dfrac{Q^2}{H}\,D + \cdot 000677\,\dfrac{LQ^2}{H}\right\} = 0 \end{array}\right\}\text{.(XIII.)}$$

We may pass over, for a first approximation, the first two terms in the brackets, and we have,

$$\left.\begin{array}{ll} \text{[In mètres]} & D = \sqrt[5]{\cdot 00222\,\dfrac{LQ^2}{H}} = \cdot 295\,\sqrt[5]{\dfrac{LQ^2}{H}} \\ \text{[In feet]} & D = \sqrt[5]{\cdot 0006769\,\dfrac{LQ^2}{H}} = \cdot 2323\,\sqrt[5]{\dfrac{LQ^2}{H}} \end{array}\right\}\text{(XIV.)}$$

This value will be rather small; and we must successively make slight augmentations to it, until the first member of the equation is reduced to, or equals, 0. The quantity which shall have led to this result will be the diameter required.

For velocities above 2 feet per second, we may take directly and simply

$$\left.\begin{array}{ll} \text{[In mètres]} & D = \cdot 298\,\sqrt[5]{\dfrac{LQ^2}{H}} \\ \text{[In feet]} & D = \cdot 235\,\sqrt[5]{\dfrac{LQ^2}{H}} \end{array}\right\}\ldots \text{(XV.)}$$

I need say nothing on the determination of H and L; the equation (VII.) gives them by a simple transposition.

11. Let us take some examples of the determination of discharges and diameters:—

Ex. 1.—We have a conduit of (·25 mètr.) ·820225 feet diameter, and (1450 mètr.) 4757·3 feet long: required the volume of water it will discharge per second, with a head of (5·32 mètr.) 17·454 feet?

We have here D = ·820225 feet; H = 17·454 feet; L = 4757·3 feet; and L + 37·2 D = 4787·816 feet. Consequently (X.),

$$Q = -\frac{\cdot 0709 \times (\cdot 820225)^2 \times 4757{\cdot}3}{4787{\cdot}816} + \sqrt{\frac{1477{\cdot}06 \times 17{\cdot}454 \times (\cdot 820225)^5}{4787{\cdot}816} + \left(\frac{\cdot 2325 \times 4757{\cdot}3 \times (\cdot 820225)^2}{4787{\cdot}816}\right)^2}$$

$$= -\cdot 047376 + \sqrt{1{\cdot}9989 + \cdot 024155}$$
$$= -\cdot 047376 + 1{\cdot}423 \quad = 1{\cdot}37924 \text{ cubic feet per second,}$$

the quantity required (all the measures being in English feet). The simplified formula (XI.) would have given

$$Q = 1{\cdot}4185 - \cdot 04767 = 1{\cdot}3708 \text{ cubic feet.}$$

That for great velocities (XII.), and applicable to this case, in which the velocity is 2·6 feet per second, would have given 1·357 cubic feet.

Ex. 2.—Required the diameter of a conduit, 2483·64 feet (757 mètr.) long, and which shall convey 3·14317 cubic feet (·089 mètr. cub.) per second, with a head of 3·2809 feet (1 mètr.)?

Putting these numerical quantities in the equation (XIII.), it becomes, all reductions made,

$$D^5 - (\cdot 22827\,D^2 + \cdot 075811\,D + 5{\cdot}0604) = 0.$$

Neglecting the first and second terms, we have

$$D = \sqrt[5]{5{\cdot}0604} = 1{\cdot}383 \text{ feet.}$$

This value of D, put in equation (XIII.), will be found too small; by gradually increasing it, we shall find, by a few trials, that the value 1·4127 feet for D, will reduce the first member of the equation to 0, and will be the diameter sought.

The formula for great velocities (XV.), and in this case v exceeds 2 feet per second, would have given

$$D = \cdot 235\,\sqrt[5]{\frac{2483{\cdot}64 \times (3{\cdot}143)^2}{3{\cdot}2809}} = 1{\cdot}383 \text{ feet.}$$

[We shall next month proceed to the author's consideration of conduits terminated by adjutages.]

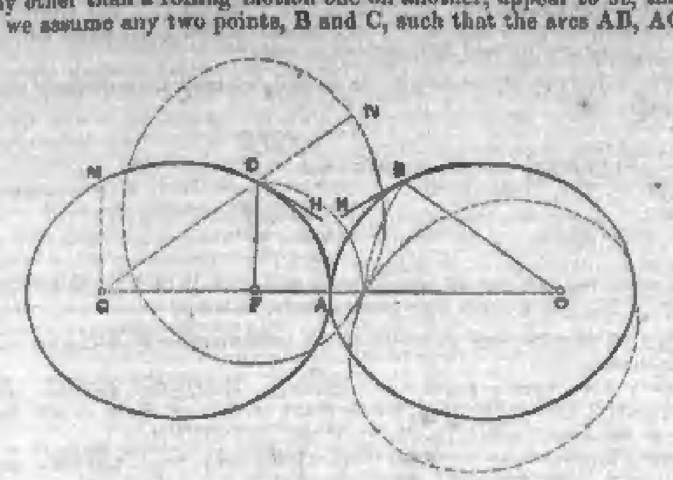
REVOLVING ELLIPTICAL WHEELS.

SIR—Having had occasion to seek for some simple means of producing a variable motion of rotation round one fixed axis from a uniform motion round another, I have been led to observe a property of the ellipse, which as it was new to me, may perhaps prove so likewise to some, at least, of your readers.

It is, that if two equal and similar cogged wheels of elliptical form, be geared together as represented in the annexed figure (which is a drawing of the *pitch lines* of such wheels, without the cogs), the teeth will continue to act upon one another during an entire revolution, with perfect regularity; and the motion of the one axis will be transferred to the other—not uniformly, but subject to a variation in velocity, the nature and amount of which may be easily calculated. By such an arrangement, therefore, a variable motion may be produced from a uniform one, in a manner comparatively simple and easily available,—capable of transmitting a force of any amount with certainty and precision. There are, probably, many cases in which some such arrangement would be found convenient; and I am inclined to believe that it is not possible to find any more simple means of attaining the object.

The conditions which must be fulfilled in order that any two curves—supposed to act in the manner represented, from fixed

centres of rotation—O and F, should continue in contact without any other than a rolling motion one on another, appear to be, that if we assume any two points, B and C, such that the arcs AB, AC,



measured from the original point of contact A along the periphery of each curve, be equal in length:

1st. The sum of the vectors FC, OB, must be equal to FO; and,

2nd. That the sum of the angles FCH, OBK, made by the vectors with tangents at the points B and C, must be equal to π, or 180°.

For unless the first of these conditions be fulfilled, it appears plain, that when, by the motion of the axis at O, the one curve shall have assumed the position represented by the dotted periphery, the point B having been brought to the position B', the point C would not be, as it should be, in contact; and if the second were not fulfilled, the curves would *intersect* at some other point, instead of having a common tangent at B'.

I need not take up your valuable space by entering into any detailed proof that these conditions are fulfilled by equal and similar ellipses working on foci, as a very slight acquaintance with the properties of the ellipse is sufficient to show that such is the case. That they may not possibly be fulfilled by some other more complex curves, I do not venture to assert, as the problem would be one of such extreme intricacy with regard to any other than equal, similar, and symmetrical forms; but I do not regard it as probable that any such curves can be found.

This principle would enable us to obtain motions of rotation of different *degrees of variation*, but of the same character—viz. with one maximum and one minimum velocity in the course of each revolution, according to the excentricity of the ellipses made use of. The revolution of the one wheel is necessarily conterminous with that of the other, but is described at a variable rate; the nature and amount of which variation may be readily ascertained, either analytically by means of the formula subjoined, or by the merely mechanical process of drawing an ellipse of the assumed excentricity, and drawing right lines from any point on the periphery to each of the foci; since it will appear plain, on consideration, that, for any assumed point C, CFA represents the angular motion at F due to the angular motion CGA, or BOA, at O.

To deduce an analytical formula applicable to the calculation of these angles, we take the polar equation of the ellipse with regard to focus G and origin GA, viz.

$$l = \frac{a^2 - c^2}{a - c \,.\, \cos\theta},$$

in which a = semi-major axis, and c = the linear excentricity.

Hence we find that the angle CFA, or ϕ, representing the angular motion round F, due to the angle CGA, or θ, round O, must be such that

$$\frac{a^2 - c^2}{a - c \,.\, \cos\theta} + \frac{a^2 - c^2}{a - c \,.\, \cos\phi} = 2a;$$

since, in order to fulfil the first of the conditions which we have shown to be required, H or Gm + Gc must be equal to FO or $2a$.

From this we can readily derive, by ordinary algebraical processes, the expression,

$$\phi = \cos^{-1}\left\{\frac{(a^2 + c^2) \,.\, \cos\theta + 2ac}{a^2 + c^2 + 2ac \,.\, \cos\theta}\right\},$$

a form easily calculated for any given values of the constants.

This action is far more simple, both in theory and practice, than that which has been already made use of—elliptical wheels working from the centres—the major axis of the one being placed at the commencement in the same straight line with the minor axis of the other. By combinations of the two, a variable motion of almost any regular periodic character may be attained, by due care in assigning the proportions of the constants; and great facilities thereby afforded for counteracting the effects of any irregularities in the motion of machinery which other circumstances may have induced.

In many cases it would be possible to economise power and space by such application; and in the hope that these hints may prove serviceable to some of your many readers, I have been induced to trouble you with this trifling communication, which you are welcome to deal with in whatever manner may prove convenient.

Southampton, WILLIAM DAVISON.
February 20th, 1850.

P.S. Since writing the above, I have seen a small planing machine at Mr. E. P. Smith's engine factory, in this town, to which elliptical wheels, acting in the manner described, had already been applied, with ingenuity and success, to retard the forward motion, and accelerate the return motion, of the cutting tool. I was not aware that the principle had been applied; but as it is certainly far from being generally known, and as it appears to me capable of being applied in many ways with advantage, the publication of the above sketch, thus divested of all pretensions to being the first notice of the principle involved, may still prove useful.

Southampton, March 12th, 1850.

THE SMYRNA STEAM FLOUR MILLS AND THE WATT AND WOOLF STEAM-ENGINES.

WITH reference to an article on these subjects in our last number, we have received a communication from Messrs. Joyce & Co., of Greenwich, which we now insert, and to which we shall append a few observations. It is as follows:—

TO THE EDITOR OF THE CIVIL ENGINEER AND ARCHITECT'S JOURNAL.

SIR—In your number for last month, which contains an account of the steam-engines and flour mills recently constructed by us for Smyrna, you have questioned the fact of those engines consuming "*less than 3lb. of coals per horse-power per hour;*" and add, that you cannot believe such a statement to have been made with our sanction; we should manifestly be wanting as well in a natural desire to do justice to ourselves as in a proper regard for our professional reputation, did we not avail ourselves of your pressing invitation, or challenge as we may rather call it, to verify or disclaim that statement through the medium of your columns. We shall therefore begin by saying that such allegation was made with our entire sanction. So far, however, from its being so extraordinary and unprecedented a performance as to have furnished grounds for your unqualified scepticism, we find *you* have long since borne testimony of having *witnessed "the gratifying fact"* "that a rotatory fly-wheel engine for land purposes can be made to do with *3lb. of coal* per horse-power per hour;" for if you will turn to your *Journal*, Vol. V., p. 109, you will find an article emanating from your pen, in which you report a double-cylinder engine constructed by Messrs. Rennie, and erected on the premises of Mr. Thomas Cubitt at Pimlico, to be working at 2½ lb. of Graigola coals per horse power per hour; neither is this "the full indicated power," but the actual duty, you yourself having deducted from the indicator diagrams an ample allowance for "friction, the power consumed by the pumps, &c.," a deduction which you seem to infer *may not* have been made in *our case*.

As the Smyrna engines could not have been put to work until after their erection at Smyrna, we cannot furnish you with any indicator cards of *their* performance; but we can, if you think it necessary, after reference to your notice of the Pimlico engine, hand you indicator cards of other engines constructed on this principle by us, from which you will see that the statement made by the public journals was a very moderate representation of their rate of consumption.

We do not profess, as you suppose, to have made any new or important discovery in the principle of double-cylinder expansion. All we claim is the simplification of the arrangements by which the number of parts, the weight of material, and amount of workman-

ship are proportionately reduced. Besides an obvious decrease of cost resulting from these improvements, it is manifest that the dispensing with several working parts, as the parallel motion, beam and its gudgeons, connecting-rod, &c., must, to some extent, (by reducing the friction, *vis inertia*, and momentum), economise power; and we think it requires no great stretch of credulity to believe that *some* economy of fuel must arise by these reductions from the arrangement in the Pimlico engine, and which you report to be working with 2¼ lb. per horse-power per hour—certainly an excellent performance, but not in any way superior to our best engines.

Having said thus much in justification of our claim to notice, and in confirmation of some of the facts given in the public journals, we think it will not be out of place to advert, as an interesting matter of history, to some of your remarks when treating of double-cylinder expansion, especially as regards the first introduction of expansive steam, both in the single and double cylinder, or in what you have termed the "Watt and Woolf engines," as well as to some other observations you have made on the subject.

It ought to be more generally known than it appears to be, that the credit of having first propounded "double-cylinder expansion" is due to Jonathan Hornblower, and not (as you have assumed, and is very frequently supposed) to Arthur Woolf. Hornblower patented the system, with ample and efficient details, in 1781; that is to say, twenty-three years before 1804, the year in which you have stated Woolf published the discovery. The following abstract from Hornblower's specification will show that he fully describes this species of engine.

"*First, I use two vessels in which the steam is to act, and which in other engines are called cylinders. Secondly, I employ the steam after it has acted in the first vessel, to operate a second time in the other by permitting it to expand itself, which I do by connecting the vessels together, and forming proper channels and apertures whereby the steam shall occasionally go in and out of the said vessels, &c.*" The description and illustrations of Hornblower gave a complete arrangement of valves and other details, and rendered the system perfectly practical, so as to leave nothing wanting to the full development of the double-cylinder expansive engine. Most of what has since been done is due rather to the progressive advances towards a more perfect system of manipulation, and to that simplification and just proportioning of the parts which experience only could have warranted. What Woolf did was to bring a mind of a highly practical turn to bear on Hornblower's system, and in this he was so successful as to be fully entitled to rank as one of the first on the list of eminent constructors; for, although commencing as he did under a delusion and a fallacy, as regards the rate at which steam decreases in pressure while expanding, there is no doubt that it is entirely owing to his ready appreciation of the value of high steam when used expansively, and to the practical skill by which he made it available in the mining operations of Cornwall, in despite of practical difficulties and (more formidable still) of a *powerful* and *prejudiced* opposition, that Cornish mining has continued to be of its present extent and importance—since, but for the large reduction in quantity of fuel consumed by pumping-engines from what it was in the days of Watt, many now profitable mines must have been abandoned or remained unworked, as the cost of fuel would have exceeded the value of the ores, and precluded those further researches which have from time to time led to the discovery of the most valuable mining treasures. We may add also the more important fact, that it was in a great measure owing to the economical results as regards fuel, resulting from Woolf's success in Cornwall, that the expansive system has obtained so generally the sanction of our best practitioners, as is evinced by its almost universal introduction.

The pumping-engines of Cornwall are, with scarcely an exception, constructed on the principle of expanding steam in one cylinder; and *you are quite right* in stating, that the double-cylinder system is inferior for *pumping* purposes.

There is no question that single-cylinder expansion, IF the load can duly be proportioned to the effort of the steam from its first impact on the piston to its minimum of effective attenuation, will produce a greater absolute impulse, or, as it is termed, a better duty for the volume of steam consumed, than if the medium were a double cylinder. It is thus that the power of the single cylinder is given out in the pumping-engines of Cornwall; and whereby the consumption of coal has been brought as low as 1·75 lb. per horse-power per hour in the best example, for by the introduction of the plunger-pump, the power of the engine *is*, when the piston is subjected to the highest steam pressure (that is to say, before the supply from the boiler is cut off), exerted to overcome the *vis inertia* of the pit work, besides its unbalanced weight, the column of water being then at rest. Once in motion, the duty is that of overcoming little more than mere gravity; and ultimately the extreme expansion of the steam, as the piston approaches the bottom of the cylinder, serves to check the momentum of the pit-work. The column of water is raised on the return stroke, not by the direct effort of the steam, but by the gravity of the unbalanced weight of the pitwork. The piston of the engine ascending in equilibrio, as regards steam pressure, it will readily be perceived, that by these arrangements, the efforts of high steam at, and a little beyond, the commencement of the descending stroke, its subsequent expansion as the *vis inertia* is being overcome, and its gradual attenuation as it approaches the termination of its course (where the efforts of momentum and pressure should both be exhausted), is better and more simply, as well as more philosophically employed than it could be by the double cylinder; wherein the main distinctive feature is an approximation to uniformity of effort, and which is, on that account, so far inapplicable to the moving a load presenting the changes of resistance just stated.

It will be corollary to the preceding conclusions, that the importance of preserving a due relation between the power and the load, renders it as desirable that the power of a rotatory machine should preserve its uniformity, as that the power of a pumping-engine, under Cornish arrangements, should be unequal. Hence it is solely owing to this approach to uniformity of effort, that double-cylinder expansion possesses any advantages over the single cylinder whenever the power is employed to produce rotation.

We believe *you* will find you are wrong in stating, that single-cylinder expansion "is very commonly adopted in cotton spinning;" for, on the contrary, IF we are correctly informed, the employment of double-cylinder expansion is becoming very extensive in the cotton factories; and manufacturers are thereby enabled to spin cotton thread as fine as can be produced by water-power—a result wholly unattainable by single-cylinder expansion.

It is common to call the fly-wheel a reservoir of power, and it is quite true that it is so; but this property, imperfectly understood, leads to a popular mistake. The notion that revolving bodies must rotate uniformly, is so closely allied to our impressions regarding circular movement, that it is difficult to divest the mind of the idea that it is otherwise; and hence it is seldom duly considered, that to be a reservoir of power, the fly-wheel must have an intermittent velocity.

The fact, however, is, that so far from being, in any instance whatever (as it is frequently supposed) a perfect equaliser of unequal efforts, it is entirely owing to the necessary changes in its velocity that it becomes the reservoir of those excesses of power which arise from unequal impulses; since, as is obvious, such excesses can only be absorbed into the fly-wheel by the fly-wheel acquiring an increased velocity; and that they can only be given out again when required to overcome the load or resistance by losing the momentum due to the increased velocity, and consequently losing the excess of velocity the fly-wheel had acquired. Or it may be more clearly stated thus: the velocity, and consequent momentum of the fly-wheel, are conjointly increased or diminished, in an assigned proportion, as either the load or the effect to increase it are in excess.

We see, therefore, that however the dynamic efforts of expanding steam may economise fuel, its great inequality of effort, when given through the medium of a single piston, would forbid us to avail of that property to such an extent as to be of an appreciable practical value in cases where great uniformity of motion, as in cotton spinning, grinding corn, and several other delicate operations, are the prime consideration.

Even a perfect uniformity of effort on the piston, must, in all cases when applied to a reciprocating engine, entail some inequality of motion in the mill work. Such inequality, however, is reduced to a very small amount, by the employment of a pair of either single-cylinder non-expansive steam-cylinders, or of double cylinders acting expansively. We need not add, however, that the double-cylinder system must (as *you* have properly shown in *your* notice of the Pimlico engine) prove by far the most economical as regards fuel. We are, &c.

Greenwich Iron Works, W. Joyce & Co.
March 18th, 1850.

*** Our professional brethren will not fail to perceive, that the letter by Messrs. Joyce and Co. is of a compound nature. In part, it is a reply to the remarks we made in our last number; in part, it is historical, and elucidatory of the action of the fly-wheel, and of the systems of pumping, as adopted in Cornwall;

in part, it accords with the opinions we have expressed; and, in part, it gives a tone and colouring to our observations, not justified by the statements we have made. Divested of extraneous matter, Messrs. Joyce and Co. candidly acknowledge to the following:—

That it was with their *entire sanction* and approval, our contemporaries asserted that in engines constructed by them, the consumption of fuel is less than 3 lb. per horse-power per hour; *while, under the old system, it is about* 12 lb.

That the Smyrna Steam Flour Mills had not been put to work in this kingdom (which, of course, is what we expected)—therefore, that the given rate of consumption, per horse-power per hour—*equal to* 3 lb., as above—was not the result of experimental tests made with those engines, but of other steam-engines made by the firm.

That they do not profess to have made any new or important discovery in the principle of double-cylinder expansion (nor did we suppose that they had contemplated making any such profession, notwithstanding their assumption to the contrary):—they state, therefore, all that they claim is, the simplification of the arrangements by which the number of parts, the weight of the material, and the amount of workmanship, are proportionably reduced; and, by which, there is a decrease in the cost of construction, and a diminution of friction, *vis inertiæ*, and momentum.

Messrs. Joyce and Co. acknowledge, that we are "quite right" in the statement we have made, that the double-cylinder system is, for pumping purposes, *inferior* in effect to the single-cylinder engine; and they append the following remarks:—"There is not a question that *single-cylinder expansion*, if the load can duly be proportioned to the effect of the steam, from its first impact on the piston to its minimum of effective attenuation, *will produce a greater absolute impulse*, or, as it is termed, *a better duty*, for the volume of steam consumed, *than if the medium were a double-cylinder.*"

After these candid admissions, there are but few differences of opinion between Messrs. Joyce and Co. and ourselves. Those differences, however—few though they be—are of such importance, *practically*, that we must be permitted to make some comments.

Corroborative of the correctness of their statements, as to the superior yield of power by double-cylinder expansion, by a given consumption of fuel, over single-cylinder expansion, Messrs. Joyce and Co. bring to their aid some statements, published by us, in the *Journal* for April, 1842.

We feel much indebted to the Messrs. Joyce, for having drawn our attention to that article, published by us so far back as eight years ago. Messrs. Joyce and Co., however, in making reference to that article, have made an *ex parte* statement. They have, in that instance, and in others, when alluding to our remarks, shown more ingenuity than ingenuousness, by making it appear that our observations are *as they could wish them to be*, rather than as what they are. In illustration, we will make a few extracts from the paper published by us in 1842, which will develope a wonderful coincidence of opinion as entertained by ourselves, and impart quite a different character to the remarks we made, than what the extracts made by Messrs. Joyce and Co. would have a tendency to impress. Those extracts are as follows:—

"A certain quantity of the power which an engine exerts is exerted in overcoming its own friction, lifting the water which has accomplished the condensation of the steam out of a vacuum, &c. The term, horse power, is used to denote the available quantity of power which an engine is capable of furnishing for any useful purpose, and is, therefore, the excess of the power produced, over the power consumed by the engine itself. Any estimate of the power of an engine, based on the assumption that the whole power exerted by the piston is the true measure of the engine's beneficial exertion, is, therefore, fallacious. An allowance of one-eighth of the power as being consumed by the engine itself, is a usual and moderate allowance.

"The amount of economy to be obtained from steam working expansively *is precisely the same, whether the expansion takes place in one or two cylinders.* The use of two cylinders serves to equalise the action, and to diminish the strain thrown upon the moving parts; but it is questionable, *whether the greatest fluctuation of pressure, when only one cylinder is used, might not be rendered equally instrumental in the production of a regular motion, simply by using a larger fly-wheel, or driving the fly-wheel at a greater velocity; and whether it is not quite as simple to increase the strength of the moving parts a little, as to add an additional cylinder and piston*, to prevent them from being subjected to so great a strain."

Again:—

"In common rotative engines, *which operate without expansion*, the ordinary consumption of coal is 10 lb. per horse-power per hour. But the horse power" (of an engine, practically) "is usually found to be about 52,000 lb. raised one foot high, in a minute, which is equivalent to 25·208 millions raised one foot high by a bushel of 84 lb. of coal. Some good engines, however, operate with an effective pressure upon the piston of 13½ lb. per square inch = 60,000 raised one foot high for a horse power; and a few ascend as high as 66,000 per horse power, without employing high-pressure steam. The engines consume *about* 8 lb. *of coal, per nominal horse power*, or 4 lb. of coal per horse power of Watt. The consumption of coal, in this engine" (the Messrs. Rennie's, or the Pimlico engine) "is 132·3 lb. per hour $\frac{132 \cdot 3}{52 \cdot 74}$ = 2·5 lb. per horse power, per hour."

In the preceding extracts, it will be perceived that we have made a marked, and an unerring distinction, between the *nominal* and the *actual* duty of steam-engines, and the quantities of coal consumed in either case; and that we have stated the average consumption of coal, in the best engines, to be 8 lb. per horse-power per hour when estimated on the nominal, and 4 lb. when estimated on the actual power. And we have further qualified our statements, with respect to the duty of Messrs. Rennie's engine, by stating that when, for the actual duty of the single-cylinder engine, the consumption is 4 lb. per horse-power per hour, it is at times when the steam is not expanded, and not at high pressure, both of which, when combined, would reduce the amount of fuel as usually consumed.

These statements are very different to those made with the expressed sanction of Messrs. Joyce and Co., which make it appear that their engines consume less than 3 lb. per horse-power per hour, "*while engines under the old system consume about 12 lb.;*" and which, as it was likely to mislead the public, called forth our remarks and animadversions. If 12 lb. per horse-power per hour be given on the *nominal power* of the single-cylinder engine, so also ought the 3 lb. on the double-cylinder. It ought, also, to be borne in mind, that the consumption of fuel, as given by Messrs. Joyce and Co., is for double-cylinder *expansion*, with high-pressure steam, and for single-cylinder *non-expansion*, with steam of low-pressure—a statement much in their favour. We therefore cannot accord with the final observation in the Messrs. Joyce's letter, "that the double-cylinder system must prove by far the most economical as regards fuel." Nor can we give our sanction to the statement made by them, that we have very properly shown that it is so. Our opinions, as published in 1842, and those recently avowed, forbid any such interpretation of our thoughts, and are diametrically opposed to any such construction of them.

The 'Treatise on Mechanics,' by Dr. Olinthus Gregory, is in the libraries of most engineers; therefore, the merit due unto Hornblower, and the controversy between him and Messrs. Boulton and Watt, are well known. Still, as Woolf brought the double-cylinder engine into practical operation, it is customary with practical men to denominate such construction, the "*Woolf-engine*." In the article to which Messrs. Joyce and Co. have referred, as published by us in 1842, we have given unto Hornblower his full meed of praise for that invention. We think, therefore, it is scarcely fair of Messrs. Joyce and Co. to assume that we were ignorant of the matter, with that article before them. In the papers of several of our contemporaries on the *Smyrna Steam Flour Mills*, which appeared with the express sanction of the Messrs. Joyce, and which we reviewed in our last number, it is called the "*Woolf-engine*," not the Hornblower; therefore, out of deference to them, and to public opinion, we gave unto the double-cylinder-engine its usual denomination.

Messrs. Joyce and Co. must pardon us for giving an unqualified contradiction to their construction of our statement, "that single-cylinder expansion is very commonly adopted in cotton-spinning." We said nothing of the kind. What we did say was this:—"*the expansive system is now very commonly adopted* to rotatory fly-wheel engines *by our best engineers;* and we ourselves were principally instrumental to its *first adaptation* to the delicate processes of the cotton manufacture." Our language, therefore, will not admit of any such twisting. We are aware that Mr. MacNaught, as stated in our last number, and that highly eminent firm, Messrs. Benjamin Hick and Son, of Bolton-le-Moors, Lancashire, are re-introducing, with certain modifications, the double-cylinder expansive engine, and applying it to cotton-spinning processes. But we must be permitted to entertain the opinions we avowed in 1842, and reiterated in our last number, as to the relative merits of the Watt and Woolf steam-engines, until we be furnished with data of the most unquestionable kind, as to the superiority of the latter.

In concluding, we must state our opinion that, although we differ from them in opinion, and they have, in some instances, given a tone and colouring to our statements not warranted by facts, we think much merit is due to Messrs. Joyce and Co., as constructive engineers and makers of steam-engines, and for the candour of their present communication.—ED. C.E. & A. JOURNAL.

REVIEWS.

Bombay Cotton, and Indian Railways. By Lieut.-Col. C. W. Grant, Bombay Engineers. London: Longman, 1850.

It seems hard to say that this book is a good one, and that we set ourselves against it; and yet it is what we are bound to say. Colonel Grant advocates a line from Bombay by Poona, in preference to that by the Malsej Ghaut: but we withhold ourselves from going into that, for though the fight may seem to be about one Ghaut or another, in truth, the whole business of railways in Western India is at stake.

The great evil hitherto has been the standing still: the government have at length been got to give leave for something being done: and it would be nothing short of madness to open the business again. The government are bound to the Great Indian Peninsula Company, and a line has been laid down for the Malsej Ghaut; and now, after so many years lost—aye, even this year lost—a beginning must be made. It may very well be said that the line by the Malsej Ghaut is the worst that could be chosen; but it has been chosen, and we must stand by it. The Colonel says—

"Sera nunquam est ad bonos mores via:"

but though it may never be too late to mend, we must say this time, it is never too early to begin. Already, a Hindoo king has undertaken a tramway from Baroda to Tankaria Bunder; and once get a railway going, other kings and other monied men will be brought to take a share in carrying out Indian railways. If the Colonel be followed, we shall have, as before, several years lost; and what may be the end no one can tell. Perhaps his railway by the Bhore Ghaut might go on—perhaps, after all, that by the Malsej Ghaut would stand good; but what is most likely, railway men in England and India would be so sickened, that no money would be forthcoming.

What was to be looked for has happened; once hold out a hope of railways for India, and every one wishes to have them in his own neighbourhood, and nowhere else, if he can help it. Col. Grant speaks out for Poona, one of the greatest towns in the west—the next to Bombay, and, as it may be said, the first step inland. We think there ought to be a Bombay and Poona railway—we strongly believe there will be one; but nevertheless, we do not wish the Malsej Ghaut line to be stayed to forward a railway to Poona. Indeed, we believe the making of the Malsej Ghaut line the best way for hastening one to Poona. Colonel Grant himself throws some light on this. Make the Great Indian Peninsula Railway, and a Poona line will be made. If, indeed, the business be opened afresh, and Poona should win the day, still five or six years will go by before anything is done; whereas, if the Great Indian Railway be opened in that time, such a start will be given, that railways must be made to Poona, and wherever they are wanted.

Colonel Grant is a man of high standing, and of great knowledge, and has fought well for his side; but we shall neither step in for him or against him. We shall leave Mr. Chapman, the founder of the Great Indian line, to answer for himself and his undertaking. All we care for is, railways for India; and that we think is best got by upholding the East Indian and Great Indian Peninsula Railways. Holding back, as we do, from the Colonel's plan, we must not be misunderstood, and thought to withhold our meed from his book. It is one of the best which has been written on Indian railways, and one our engineering brethren ought to read, as the writer having a deep knowledge of what he is about, has thrown great light upon it. He is wholly for cheap works and light engines; and he goes at some length into the details of building and working, not being one of those who pull down without setting up something in its stead. His is a book, indeed, which upholds the credit of the Indian engineers, and shows how ready our eastern brethren are to keep up their professional knowledge, and carry out everything which is new and good.

What Colonel Grant says when writing about cotton, will be read with some interest, as showing the great income got from the water-ways of India. Colonel Grant himself shows how cheaply a water-way could be made in Guzerat, between the Taptee and the Nerbudda, so as greatly to further the growth of cotton; though, as the Malsej Ghaut Railway has been put forward as a cotton railway, the Colonel, on behalf of the Poona people, wishes to show that the great cotton field is not inland, but in Guzerat. After all, he allows that railways would do some good for cotton.

The Geography of Great Britain. Part I. England and Wales. By G. Long, M.A., and G. R. Porter; the Statistical Division by Hyde Clarke. London: Baldwin, 1850. Octavo.

An exceedingly cheap and perfect work, containing a complete physical geography and political topography of England and Wales. It is of great consequence that an engineer should be acquainted with the physical geography and geology of a country, more particularly of that one of which he may be an inhabitant. In this work the rivers, valleys, mountains, and other physical characteristics are fully described. The climatology of the country has not been forgotten, and several interesting tables are given. The importance of this subject has been recently impressed on our readers by a writer in the *Journal*. Each county, with its principal places, is described with great clearness, while at the same time a full description of the trade, antiquity, and population of each place is given.

We cannot speak too highly of the statistical portion, which contains a complete view, in a condensed form, of the whole body of statistics relating to England and Wales, brought up to the present time. The population of every town, including all the new ones, is given, which is very useful. The ordinary returns merely give that of the parish, which is generally of no service, it being very different from the actual town population, which is what is required for statistical purposes. Every department of trade is attended to, the imports and exports of every article being mentioned, with the number of persons employed. The number of professional men returned for England is 117,697, architects and engineers bearing the respective proportions of 1,458 and 888. The index is well arranged, which is a point of considerable moment in a work of general reference.

Suggested Legislation, with a View to the Improvement of the Dwellings of the Poor. By G. Poulett Scrope, Esq. M.P. London: Ridgway, 1849.

Mr. Poulett Scrope has distinguished himself by the promotion of practical measures for the benefit of the working-classes, and particularly with regard to dwellings. Certainly, one of the first things to be done is to have good house-room for the whole people, and it is quite within the power of our lawmakers to do this, if they honestly wish it. Brick, stone, and lime are to be found all over the land; there are workmen enough; and, so far as that goes, a palace might be built for every one in England. There is the same plenty of material for schools and churches. There is no industrial stumbling-block.

Mr. Poulett Scrope proposes three measures—First, to exempt small tenements from rating; next, union rating; and third, facilities for granting cottage sites. The first has become a purely political discussion, and is beyond our bounds; the next may be considered a measure affirmed by the common wish, and on its way to accomplishment; the third is a step which nothing but the blindness of lawmakers can long hinder.

At length the duty has been taken off bricks, which will do something for carrying out Mr. Scrope's wishes; and we have great pleasure in congratulating the profession on the putting-down of this hurtful tax. Not only was it a hindrance in the way of enterprise and of art, but it kept thousands out of employment. It will be none the least benefit from getting rid of the excises on bricks and glass, that a great field of employment has been opened; and the next steps are abolition of the taxes on paper, carriages, and men servants—all of which, instead of being levied on luxury, are in truth levied on industry. The trade of cariage-building however high it stands in this country, is much kept down by the taxes on carriage-owners, to the great loss of masters and workmen.

Architectural Sketches—Italy (drawn on the spot by the Author); comprising Villa Outlines, Doorways, Gateways, &c. By T. C. Tinkler, Architect.

We presume from the title that it is Mr. Tinkler's object to give other illustrations of his architectural tour, besides Italy. The present part contains many designs of interest; but we would suggest to the author, as there are so many inquirers into authorities for Italian villa architecture, that it would add much to the value of the work if more details were given, and, in some cases, plans.
